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WATER RESOURCE STUDY, CIMARRON RIVER BASIN - OKLAHOMA, KANSAS, COLORADO, AND NEW MEXICO

Federal Water Quality Administration
Dallas, Texas

May 1970

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WATER RESOURCE STUDY

CIMARRON RIVER BASIN

OKLAHOMA, KANSAS, COLORADO, and NEW MEXICO

Abstract

A study has been completed to determine the need for and value of water supply storage for municipal, industrial and quality control purposes. Additional sources of municipal and industrial water supply will be needed in the basin. Storage for water quality control releases is not needed.

Prepared For

DEPARTMENT OF THE ARMY

U.S. Army Engineer District

Tulsa, Oklahoma

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UNITED STATES DEPARTMENT OF THE INTERIOR
Federal Water Quality Administration
South Central Region
Dallas, Texas

MAY 1970

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Report, "Water Resource Study, Cimarron River Basin, Oklahoma, Kansas, Colorado, and New Mexico," Federal Water Quality Administration, dated May 1970*.

Report, "Ground Water - Cimarron River Basin," U. S. Geological Survey - Water Resources Division, dated September 1966.

Report, "A Cimarron River Basin Report," U. S. Department of Agriculture, Soil Conservation Service, dated March 1967.

Report, "Irrigation Potential in the Cimarron River Basin," U. S. Department of the Interior, Bureau of Reclamation, dated October 1966 (Revised March 1969).

Letter Report, U. S. Department of the Interior, Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, dated December 5, 1969.

*In other sections of the survey report, this agency is referred to as the Federal Water Pollution Control Administration.

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I. INTRODUCTION

A. Request

In a letter dated August 27, 1962, the Deputy District Engineer, U.S. Army Engineer District, Tulsa, Oklahoma, requested the Public Health Service, U.S. Department of Health, Education, and Welfare, to ". . .make such investigations of the Cimarron River Basin as may be required to determine water quality, value, and water supply needs of areas which might be served by reservoirs in the basin. Consideration should be given to water requirements for both municipal and industrial water quality control needs for a 100-year future period. . ."

B. Authority

The water supply portion of this study was made in accordance with the Memorandum of Agreement, dated November 4, 1958, between the Department of the Army and the Department of Health, Education, and Welfare, relative to the Water Supply Act of 1958, as amended (43 U.S.C.390b). The water quality aspects were considered under authority of the Federal Water Pollution Control Act, as amended (33 U.S.C. 466 etc. seq.). Responsibility for these activities was transferred from the Department of Health, Education, and Welfare to the Department of the Interior by Reorganization Plan No.2 of 1966, effective May 10, 1966.

C. Purpose and Scope

The purpose of this study is to determine the need for and value of water supply storage to the year 2075, for water quality control purposes and municipal and industrial use in the Cimarron River Basin. Basic data for the study were obtained from State and other Federal agencies and from various publications. This data was used to evaluate the present water quality and water supply needs and projected to furnish a base for estimating future municipal and industrial requirements and waste loadings in the Cimarron Basin.

D. Acknowledgements

Appreciation is expressed to the following organizations who provided information and technical advice during the preparation of this report.

Pages 1-5 blank

State

Kansas State Board of Agriculture
Oklahoma State Department of Commerce and Industry
Oklahoma State Employment Security Commission
Kansas Geological Survey
Kansas State Board of Health
Oklahoma State Health Department
Kansas Industrial Development Commission
Kansas Water Resources Board

Federal

U.S. Department of Agriculture
U.S. Army Corps of Engineers, Tulsa District
U.S. Geological Survey

Other

University of Oklahoma, Bureau of Business Research
Kansas State University, Department of Economics & Sociology
Various municipal and industrial officials in the study area

II. SUMMARY OF FINDINGS AND CONCLUSIONS

A. Findings

1. The Tulsa District of the U.S. Army Corps of Engineers is conducting a water resources study of the Cimarron River Basin, New Mexico, Colorado, Kansas and Oklahoma. As a result of the study, the Corps of Engineers is proposing an initial and a long range plan for development in the basin. The initial plan includes construction of Englewood Dam and Reservoir at river mile 346.5 on the Cimarron River, Skeleton Dam and Reservoir at river mile 12.0 on Skeleton Creek, in the lower reaches of the basin, and the water quality control units recommended in the Corps of Engineers report, "Arkansas-Red River Basins, Water Quality Control Study, Texas-Oklahoma-Kansas," dated May 13, 1966. The long range plan includes the addition of seven multiple-purpose reservoirs.

2. The study area population, with the Oklahoma City Standard Metropolitan and Statistical Area (SMSA) excluded, has declined from 414,000 in 1910 to 385,000 in 1960.

3. The Oklahoma City SMSA population has increased from 128,000 in 1910 to 503,000 in 1960.

4. Streamflow in the Cimarron River and its tributaries is low and intermittent, particularly in the upper two-thirds of the basin.

5. Above Harper and Woods Counties, Oklahoma at the Kansas State line the quality of the Cimarron River water is satisfactory for most uses.

6. Below the Kansas-Oklahoma State line, at Harper and Woods Counties, the river is polluted with chlorides, and in certain reaches with sulfates from salt springs and from contact with natural salt deposits.

7. There are two primary salt deposits on the Cimarron River mainstem, one primary salt deposit on Salt Creek, and a secondary salt deposit on Turkey Creek.

8. One tributary, Cottonwood Creek, is degraded in its headwaters by the effluents from several sewage treatment plants upstream from Guthrie, Oklahoma. During periods of low stream flows, the dissolved oxygen concentration in the headwater area occasionally approaches zero.

9. There are five surface water supply developments in the Cimarron River Basin.

10. Total surface water use in the study area average four million gallons per day for municipal use and 15 million per day for irrigation purposes.

11. Abundant supplies of good quality ground water are available throughout the basin.

12. Total ground water withdrawal in the study area averages 30 million gallons per day for municipal and industrial use and 690 million gallons per day for irrigation purposes.

13. The U.S. Army Corps of Engineers, in their report, "Ark-Red River Basins, Water Quality Control Study, Texas-Oklahoma-Kansas," recommended construction of water quality control structures at the three primary salt sources in the basin. These structures are expected to reduce the salt load of the Cimarron River, so that water from the river will be usable.

B. Conclusions

1. The study area population (with the Oklahoma City SMSA excluded) is projected to increase to 765,000 by 2020 and 1,360,000 by 2070.

2. The Oklahoma City SMSA population is projected to increase to 1,800.000 by 2020 and 4,750,000 by 2070.

3. Additional sources of municipal and industrial water supplies will be needed in Oklahoma City, Guthrie, Stillwater, Cushing, and Enid, Oklahoma, and Liberal, Kansas.

4. Additional irrigation water is presently needed for farmlands in the study area. This need can be met from ground water sources.

5. The proposed Skeleton Reservoir on Skeleton Creek, with a yield of 37 mgd, could supplement the existing municipal and industrial water supply sources of Guthrie, Stillwater, Cushing and Enid, Oklahoma to satisfy the water supply needs of these towns to the year 2020.

6. The 44 mgd yield from the proposed Englewood Reservoir could be used beginning in 2020, to meet the increase in water needs after 2020 at Guthrie, Stillwater, Cushing and Enid, Oklahoma. Prior to 2020 the yield from Englewood could be exported to areas outside of the Cimarron River Basin.

7. Oklahoma City is expected to use the water supply yield from Federal reservoirs in Southeast Oklahoma, outside of the Cimarron River Basin.

8. Liberal, Kansas can meet its water supply needs by expanding its existing well system.

9. Water supply storage for low flow augmentation in the Cimarron River Basin is not needed at this time.

10. The water quality problem on Cottonwood Creek can be eliminated by additional treatment of the waste discharges or by piping the treated waste discharges to the Cimarron River.

11. Municipal and industrial waste discharges from Enid, Oklahoma could create undesirable algae growths in the proposed Skeleton Reservoir if the population and industry develop in the area as projected. This can be avoided by further treatment of Enid's wastes to remove nutrients.

12. Based on the cost of the most likely alternatives, the average annual benefits derived from storage yielding 37.0 from Skeleton Reservoir and 44.0 mgd from Englewood Reservoir for municipal and industrial use within the Cimarron River Basin would be $1,764,000 and $127,400 respectively.

III. PROJECT DESCRIPTION

The plans of improvement proposed by the Corps of Engineers for the Cimarron River Basin includes an initial plan and a long range plan. The initial plan (see Figure 1) consists of two multipurpose reservoirs, Englewood on the Cimarron River and Skeleton on Skeleton Creek, and the control units proposed by the Corps of Engineers in a previous report, "Arkansas-Red River Basins, Water Quality Control Study." Pertinent data on the multipurpose reservoirs proposed in the initial plan is listed on Table III-1. The long range plan includes the addition of seven multipurpose reservoirs proposed in the initial plan is listed on Table III-1. Table III-2 contains pertinent data on the seven multipurpose reservoirs proposed in the long range plan. The locations of these reservoirs are shown on Figure 1.

Table III-1

Pertinent Data on Reservoir Projects
in the
Proposed Initial Plan

	Englewood	Skeleton
General		
Project Purposes	Flood Control	
	Water Supply, Recreation and Fish & Wildlife	Water Supply, Recreation and Fish & Wildlife
Stream	Cimarron River	Skeleton Creek
River mile	346.5	12.0
Drainage area (sq. mi.)	5,322	547
Elevation (feet, msl)		
Top of dam	2,177.5	1,004.0
Maximum pool	2,172.5	998.6
Top of flood control pool	2,149.5	-
Top of conservation pool	2,109.5	989.5
Top of inactive pool	2,073.0	958.5
50-year pool	2,129.0	990.5
Stream bed	2,025.0	924.0
Storage (acre-feet)		
Flood control	440,000	-
Conservation	91,900	250,000
Inactive	139,000	30,000
Total	670,900	280,000
Area (acres)		
Top of flood control pool	15,910	-
Top of conservation pool	6,300	15,070
Water Supply		
Maximum dependable yield (mgd)	44	37

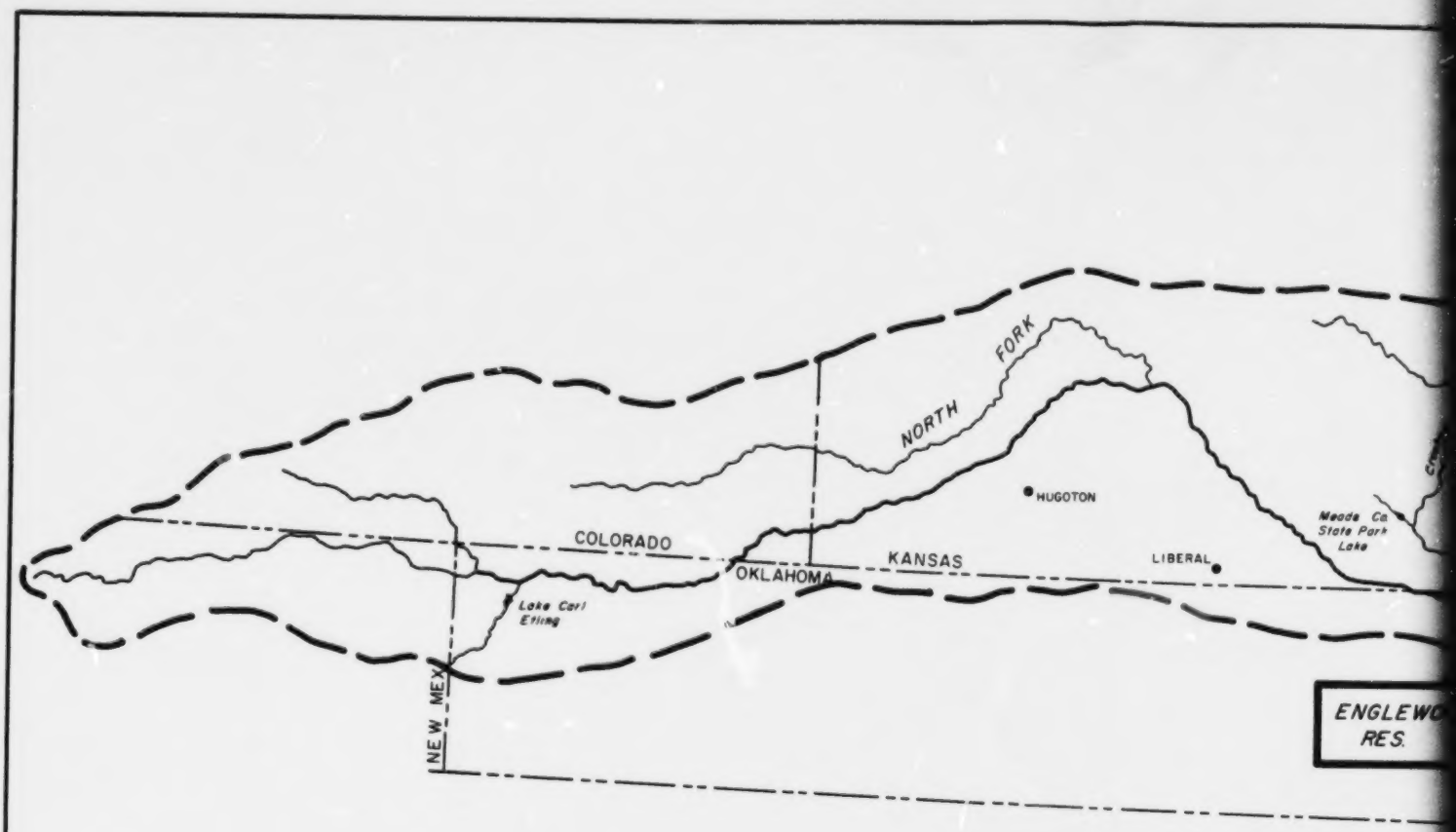
Source: U. S. Army Corps of Engineers, Tulsa District

Table III-2

Pertinent Data on Reservoirs in Long-Range Plan

	Bluff Creek	Hennessey	Buffalo Creek	Sleeping Bear	Dover	Crescent	Seward
General							
Project Purposes	Water Supply, Recreation, & F&WL	Water Supply, Recreation & F&WL	Flood Control, Water Supply, Recreation & F&WL	Flood Control, Water Supply, Recreation & F&WL	Flood Control, Water Supply, Recreation & F&WL	Flood Control, Water Supply, Recreation & F&WL	Flood Control, Water Supply, Recreation & F&WL
Stream	Bluff Cr.	Turkey Cr.	Buffalo Cr.	Sleeping Bear Cr.	Cimarron Riv.	Cimarron Riv.	Cottonwood Cr.
River mile	23.9	20.3	11.3	1.2	170.4	134.6	17.9
Drainage area (sq. mi.)	245	306	380	46	10,079	11,486	304
Elevation (feet, msl)							
Top of dam	2,018	1,177	1,748	1,740	1,154	1,050	1,036
Maximum pool	2,013	1,172	1,743	1,735	1,148	1,044	1,031
Top of flood control pool	-	-	1,723	1,719	1,132	1,030	1,024
Top of conservation pool	1,994	1,169	1,679	1,681	1,110	1,011	1,018
Top of inactive pool	1,964	1,144	1,651	1,657	1,069	942	973
50-year pool	1,996	1,171	1,703	1,701	1,129	1,027	1,024
Streambed	1,933	1,094	1,619	1,617	1,044	933	956
Storage (acre-feet)							
Flood control	-	-	147,000	21,000	508,000	660,000	79,500
Conservation	41,500	110,000	29,000	3,900	268,000	647,000	255,000
Inactive	24,000	25,000	32,500	3,900	120,000	56,000	9,000
Total	65,500	135,000	208,500	28,800	896,000	1,363,000	343,500
Area (acres)							
Top of flood control pool	-	-	5,300	1,140	33,000	44,300	14,300
Top of conservation pool	2,750	7,150	1,700	250	17,100	30,100	11,800
Water Supply							
Maximum dependable yield (mgd)	13	20	8	1	54	134	52

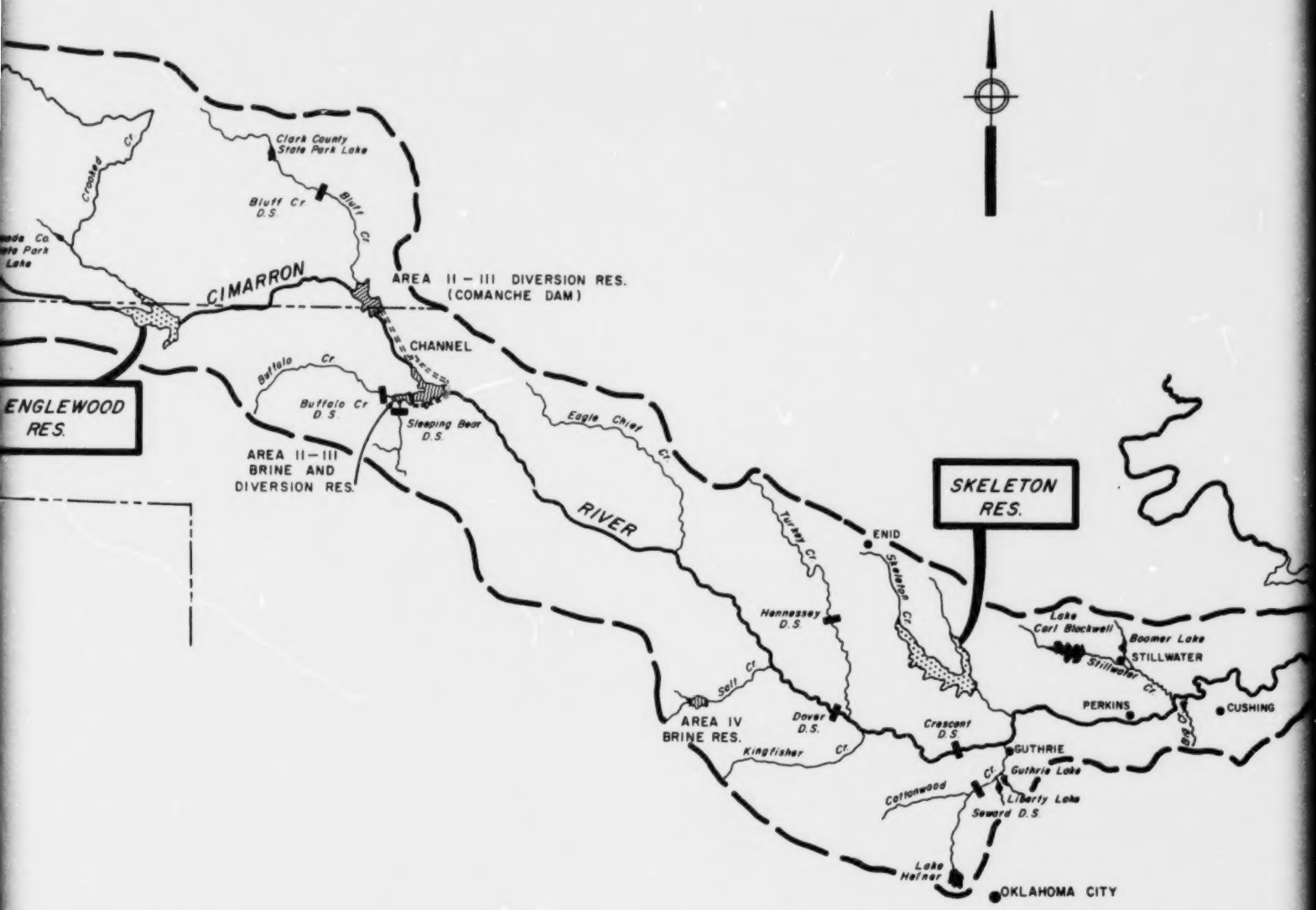
Source: U. S. Army Corps of Engineers, Tulsa District



LEGEND:

- EXISTING FEDERAL RESERVOIR
- EXISTING NON-FEDERAL LAKE
- PROPOSED SALT CONTROL RESERVOIR
- PROPOSED RESERVOIR – INITIAL PLAN
- DAMSITE – LONG-RANGE PLAN

A



WATER SUPPLY & WATER
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SOUTH CENTRAL REGION

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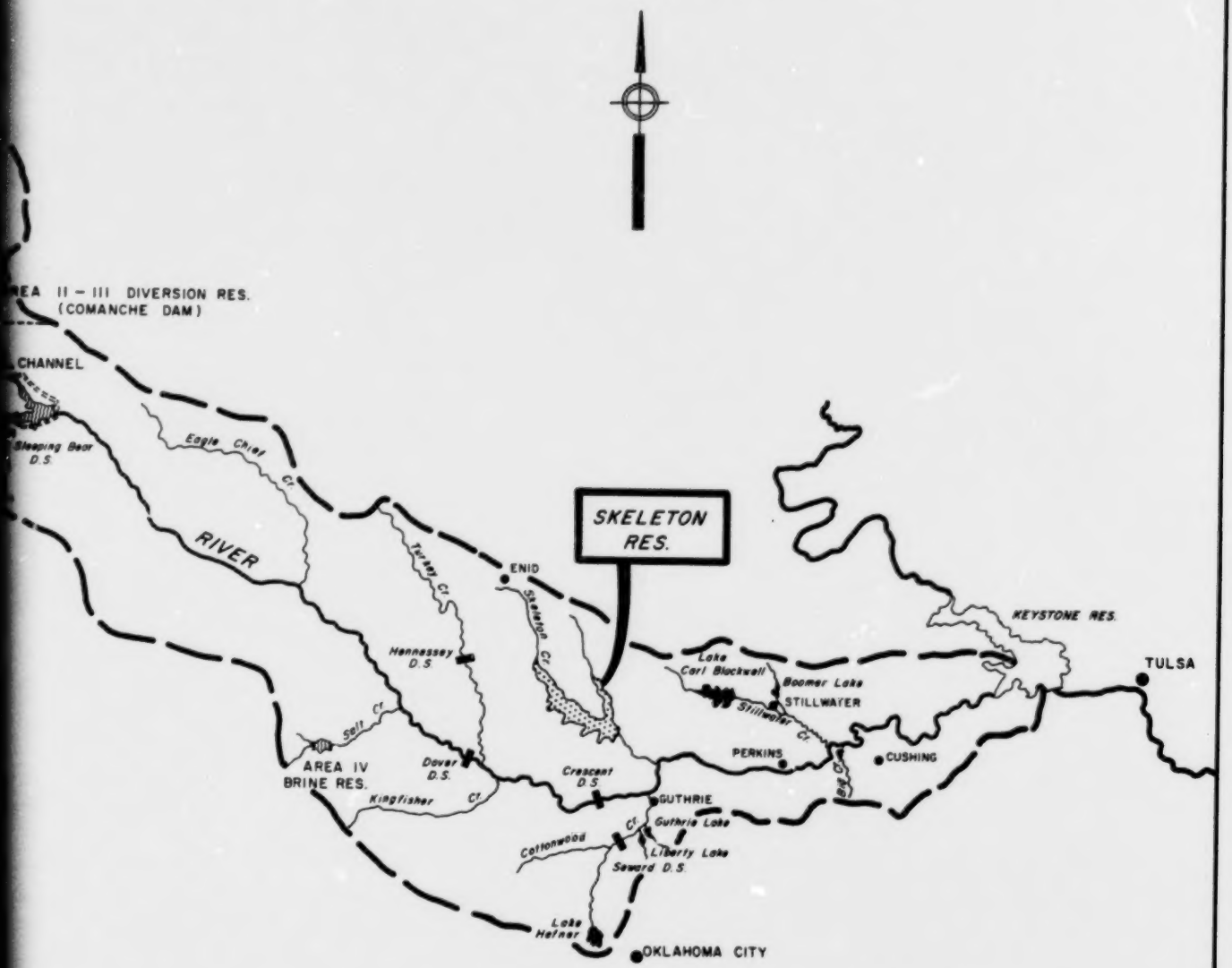


WATER SUPPLY & WATER QUALITY CONTROL STUDY
CIMARRON RIVER BASIN
OKLAHOMA – KANSAS – NEW MEXICO – COLORADO

INITIAL AND LONG-RANGE PLANS OF DEVELOPMENT

UNITED STATES DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
SOUTH CENTRAL REGION — DALLAS, TEXAS

FIGURE 1

IV. BASIN AND STUDY AREA DESCRIPTION

A. Location and Boundaries

The Cimarron River rises in the northeast corner of New Mexico near Raton, and flows eastward through the Oklahoma Panhandle, the southeastern corner of Colorado and the southwestern corner of Kansas. The river then reenters Oklahoma flowing southeasterly to join the Arkansas River in Keystone Reservoir, near Tulsa, Oklahoma (see Figure 2). The Cimarron River flows 700 miles and drains approximately 19,000 square miles, of which 4,926 are noncontributing. The drainage area consists of 1,150 square miles in New Mexico, 2,100 square miles in Colorado, 6,450 square miles in Kansas and 9,300 square miles in Oklahoma. The basin is over 600 miles long and varies in width from 25 to 50 miles.

The study area for this investigation encompasses the Cimarron River drainage basin and includes 33 counties lying within or bordering the basin, as shown on Figure 2. The area of study includes those counties which are expected to exert water supply demands or return wastes to the stream in the project area. The Oklahoma City Standard Metropolitan Statistical Area (SMSA), comprised of Canadian, Cleveland, and Oklahoma Counties, was included in the study area since treated waste effluents from Oklahoma City and several suburbs are discharged into the Cimarron Basin. The study area does not include Tulsa and Osage Counties, Oklahoma; Ford, Gray, Kearny, and Hamilton Counties, Kansas; and Powers County, Colorado, which were included in the study area used by the Tulsa District, Corps of Engineers.

B. Topography and Geology

The Cimarron River rises in New Mexico, draining mountains and plateau with a maximum altitude of 8,000 feet mean sea level (msl). Except for portions of its course which pass through a few valleys, the river in New Mexico flows through a narrow sandstone canyon, entering Oklahoma at approximately 4,600 feet msl. In Oklahoma, the canyon widens into a valley about two miles across, 60 miles long, and extends into Kansas. Near Hugoton, Kansas, the channel narrows and for 60 miles the riverbed resembles a small dry creek. Little water passes this reach, except in periods of extreme flood conditions.

This dry stretch marks the division between the upper and lower rivers. Only the continuous channel indicates that the river should be considered a single stream. Topography of the upper reach of the watershed is generally broken and rough.

North of Liberal, Kansas water reappears in the stream channel and the flow gradually increases downstream. In places, deep ravines have cut into red beds, and in northwestern Oklahoma the river passed through heavy gypsum and rocksalt deposits. Salt plains have developed on both sides of the river as a result of discharges from large salt water springs in Woods and Harper Counties, Oklahoma.

C. General Features

The Cimarron River Basin study area is sparsely populated. Approximately 90 percent of the population resides in the lower third of the study area, which includes the Oklahoma City metropolitan complex. The chief sources of income in this area are oil production, manufacturing, and government payrolls. In the upper two-thirds of the the study area, the economy is dependent on gas production (from the extensive Oklahoma Panhandle and Southwestern Kansas gas fields), livestock raising, and cash grain farming (primarily winter wheat crop).

The area has a warm semiarid to subhumid climate. Rainfall varies from 15 inches per year in the western section of the basin to 35 inches per year in the eastern section of the basin.

V. ECONOMY

A. Present

1. Population - The total study area population has increased over the past fifty years from 542,000 in 1910 to 888,000 in 1960. This increase in population is due to the rapid growth of the Oklahoma City metropolitan area. The Oklahoma City SMSA population has grown from 128,000 in 1910 to 503,000 in 1960, and now comprises approximatly 57 percent of the total study area population. The remainder of the study area has decreased in population from 414,000 to 385,000 over this same time period. Table V-1 shows the 1910, 1950 and 1960 populations of the 33 counties in the study area.

The area inhabitants have also shifted from the rural sections of the study area to the urban areas. In 1910 there were 142,000 urban residents in the study area. By 1960, this urban population had increased to 648,000. During this same time period, the rural population declined from 400,000 to 240,000. Table V-2 shows the 1960 population of the principal communities in the study area.

2. Employment - Total employment in the study area has gradually increased from 238,000 in 1940 to 329,000 in 1960. The ratio of population to labor force has decreased from 2.75 to one in 1940 to 2.64 to one in 1960. During this time the majority of the labor force has been service employed. Total service employment in 1940 was 56 percent of the total study area labor force and by 1960, had increased to 75 percent.

Agriculture and manufacturing industries have been the next largest employers in the study area. In 1940, 21 percent of the labor force were agriculturally employed and seven percent were employed in manufacturing industries. By 1960, manufacturing employment had increased to 10 percent of the total labor force, while agriculture employment decreased to eight percent. Table V-3 lists the study area's employment by groups.

3. Industry

a. Minerals - The principal minerals being extracted in the study area are oil and gas. Deposits of gypsum, volcanic ash, limestone and dolomite, sandstone, salt, and clay are also present in the area, but are not being extracted as rapidly as the oil and gas deposits. In 1961,

Table V-1

County Populations
1960, 1950 and 1910

State	County	1960 Population	1950 Population	1910 Population
New Mexico	Union	6,068	7,372	11,404
	Colfax	13,806	16,761	16,460
Colorado	Las Animas	19,983	25,902	33,643
	Baca	6,310	7,964	2,516
Kansas	Stanton	2,108	2,263	1,034
	Grant	5,269	4,638	1,087
	Haskell	2,990	2,606	993
	Morton	3,354	2,610	1,333
	Stevens	4,400	4,519	2,453
	Seward	15,930	9,972	4,091
	Meade	5,505	5,710	5,055
	Clark	3,396	3,946	4,093
	Comanche	3,271	3,888	3,281
Oklahoma	Cimarron	4,496	4,598	4,553
	Texas	14,162	14,235	14,249
	Beaver	6,964	7,411	13,631
	Harpers	5,956	5,977	8,189
	Woods	11,932	14,526	17,567
	Woodward	13,902	14,383	16,592
	Alfalfa	8,445	10,699	18,138
	Major	7,808	10,279	15,248
	Blaine	12,077	15,049	17,960
	Garfield	52,975	52,820	33,050
	Kingfisher	10,635	12,860	18,825
	Noble	10,376	12,156	14,945
	Logan	18,662	22,170	31,740
	Pawnee	10,884	13,616	17,332
	Payne	44,231	46,430	23,735
	Lincoln	18,783	22,102	34,779
	Creek	40,495	43,143	26,223
	Subtotal	385,173	420,605	414,199
Oklahoma City SMSA				
	Canadian	24,727	25,644	23,501
	Oklahoma	430,506	325,352	85,232
	Cleveland	47,600	41,443	18,843
	Subtotal	502,833	392,439	127,576
TOTAL		888,006	813,044	541,775

Source: U. S. Census of Population, U. S. Department of Commerce.

Table V-2

Principal Communities by State and County
With 1960 Population

	State	County	Town	1960 Population
1.	Colorado	Las Animas	Trinidad	10,691
2.	New Mexico	Colfax	Raton	8,146
		Union	Clayton	3,314
3.	Kansas	Grant	Ulysses	3,157
		Stevens	Hugoton	2,912
		Seward	Liberal	13,813
4.	Oklahoma	Texas	Guymon	5,768
		Woodward	Woodward	7,747
		Woods	Alva	6,258
		Garfield	Enid	38,859
		Kingfisher	Kingfisher	3,249
		Canadian	Yukon	3,076
		Canadian	El Reno	11,015
		Noble	Perry	5,210
		Logan	Guthrie	9,502
		Pawnee	Cleveland	2,519
		Payne	Stillwater	23,965
		Payne	Cushing	8,619
		Lincoln	Chandler	2,524
		Creek	Drumright	4,029
		Creek	Bristow	4,795
		Creek	Sapulpa	14,282
		Cleveland	Norman	33,412
		Blaine	Watonga	3,252
		Oklahoma	Bethany	12,342
		Oklahoma	Del City	12,934
		Oklahoma	Edmond	8,577
		Oklahoma	Midwest City	36,058
		Oklahoma	Nichols Hills	4,897
		Oklahoma	Oklahoma City	324,253
		Oklahoma	The Village	12,118
		Oklahoma	Warr Acres	7,135

Source: U. S. Census of Population, U. S. Department of Commerce.

Table V-3

Distribution of Employment for the Study Area--1940, 1950 and 1960

	1940			1950			1960		
	Number	Per-cent	National Percentage	Number	Per-cent	National Percentage	Number	Per-cent	National Percentage
1/ *Agriculture	57,567	21.4	17.5	46,414	15.1	11.3	27,450	8.1	6.3
1/ Mining	10,608	3.9	1.7	11,799	3.9	1.4	11,911	3.5	1.0
Manufacturing	17,948	6.7	19.8	24,782	8.1	24.1	34,733	10.2	23.8
Resource Oriented	-	-	-	13,492	4.4	10.0	16,030	4.7	8.9
Furniture, Lumber & Wood Products	-	-	-	1,796	0.6	2.0	1,767	0.5	1.6
Primary Metals	-	-	-	719	0.2	1.9	436	0.1	1.8
Food and Kindred Products	-	-	-	7,111	2.3	2.5	7,721	2.3	2.8
Chemical & Allied Products	-	-	-	928	0.3	1.0	747	0.2	1.3
Other Nondurables	-	-	-	2,938	1.0	2.6	5,359	1.6	1.4
Nonresource Oriented	-	-	-	11,006	3.6	14.1	18,703	5.5	14.9
Fabricated Metals Machinery, Transportation, & Other Durable Goods	-	-	-	6,714	2.2	8.9	13,676	4.0	10.0
Textiles & Apparel	-	-	-	630	0.2	3.8	885	0.3	3.2
Printing & Publishing	-	-	-	3,662	1.2	1.4	4,142	1.2	1.7
1/ Service Industries	151,574	56.3	46.4	213,169	69.9	57.8	255,410	75.2	63.3
2/ Unemployment	31,527	11.7	14.6	9,314	3.0	5.4	10,060	3.0	5.6
Labor Force	269,224			305,478			339,564		
Total Population	741,128			813,035			897,007		
Ratio of Pop. to Labor Force	2.75			2.66			2.64		

* Includes Forestry and Fisheries.

Source: 1/ Growth Patterns in Employment by County, U. S. Department of Commerce.
2/ U. S. Census of Population, U. S. Department of Commerce.

54 million barrels of crude oil, one million barrels of gas liquids, and 900 billion cubic feet of natural gas were recovered in the study area. The primary area of natural gas extraction is the upper basin (Western Kansas and Oklahoma) while the majority of the petroleum is extracted from deposits in the lower basin (see Figure 3). Long term recovery of these minerals will eventually deplete the deposits.

Table V-4 shows the value of mineral production in the study area and the United States.

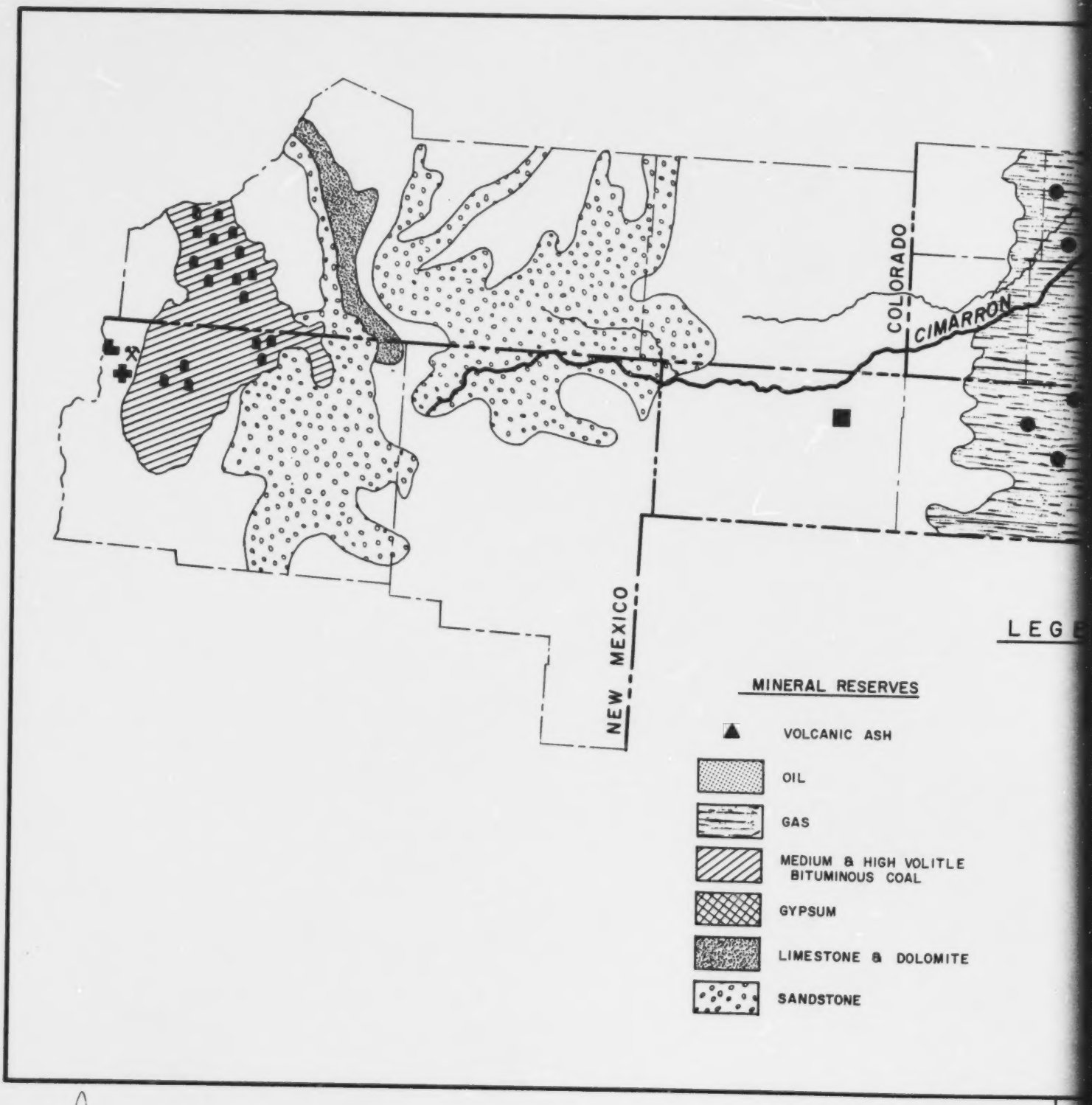
Table V-4

Value of Mineral Production in the Study Area and the U.S. 1953-1960
(1,000 constant 1960 dollars)

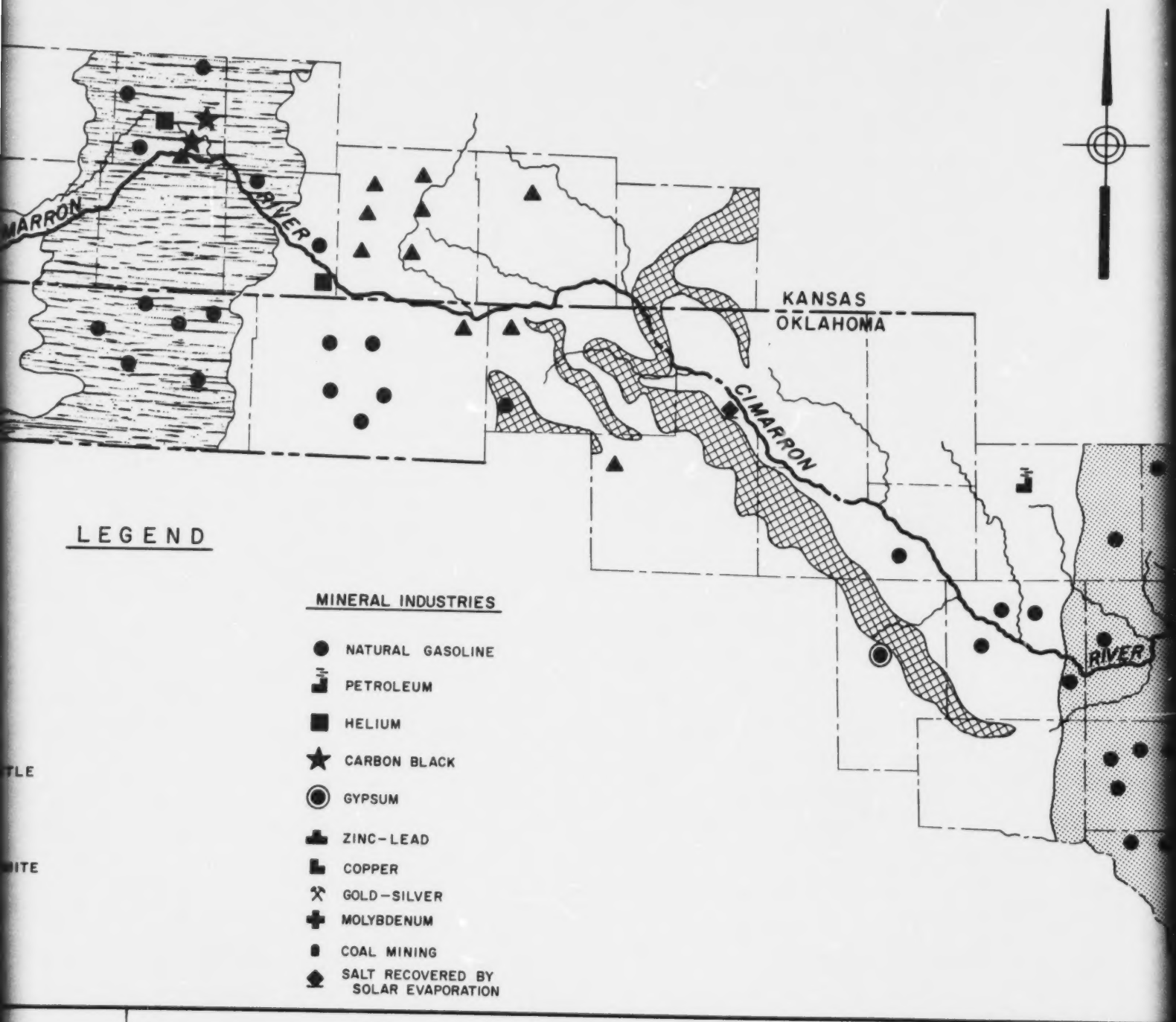
	Study Area				
Year	Upper Basin	Middle Basin	Lower Basin	Total	Nation
1953	11,631	58,007	155,698	225,336	15,909,270
1954	8,890	71,174	149,318	229,382	15,721,640
1955	12,619	77,038	154,976	244,633	17,682,470
1956	12,476	83,316	159,468	255,260	18,867,010
1957	14,068	72,797	163,336	250,201	18,673,190
1958	12,484	92,396	155,027	259,907	17,718,550
1959	14,542	107,742	148,324	270,608	18,483,500
1960	16,453	127,944	134,914	279,311	18,994,840

Source: Mineral Yearbook, U.S. Department of the Interior.

b. Agriculture - The shift to mechanical farm practices in the study area has decreased the demand for farm labor and as a result agricultural employment in the area has declined. Mechanical farm operations and other advances in farming technology have enabled farmers to increase their crop yields per acre and to reduce the total acreage harvested. This has increased the value of the farm products sold.


COLORADO
CIMARRON
NEW MEXICO
LEGE
MINERAL RESERVES
VOLCANIC ASH
OIL
GAS
MEDIUM & HIGH VOLITLE BITUMINOUS COAL
GYPSUM
LIMESTONE & DOLOMITE
SANDSTONE

A



LEGEND

MINERAL INDUSTRIES

- NATURAL GASOLINE
- PETROLEUM
- HELIUM
- CARBON BLACK
- GYPSUM
- ZINC-LEAD
- COPPER
- GOLD-SILVER
- MOLYBDENUM
- COAL MINING
- SALT RECOVERED BY SOLAR EVAPORATION

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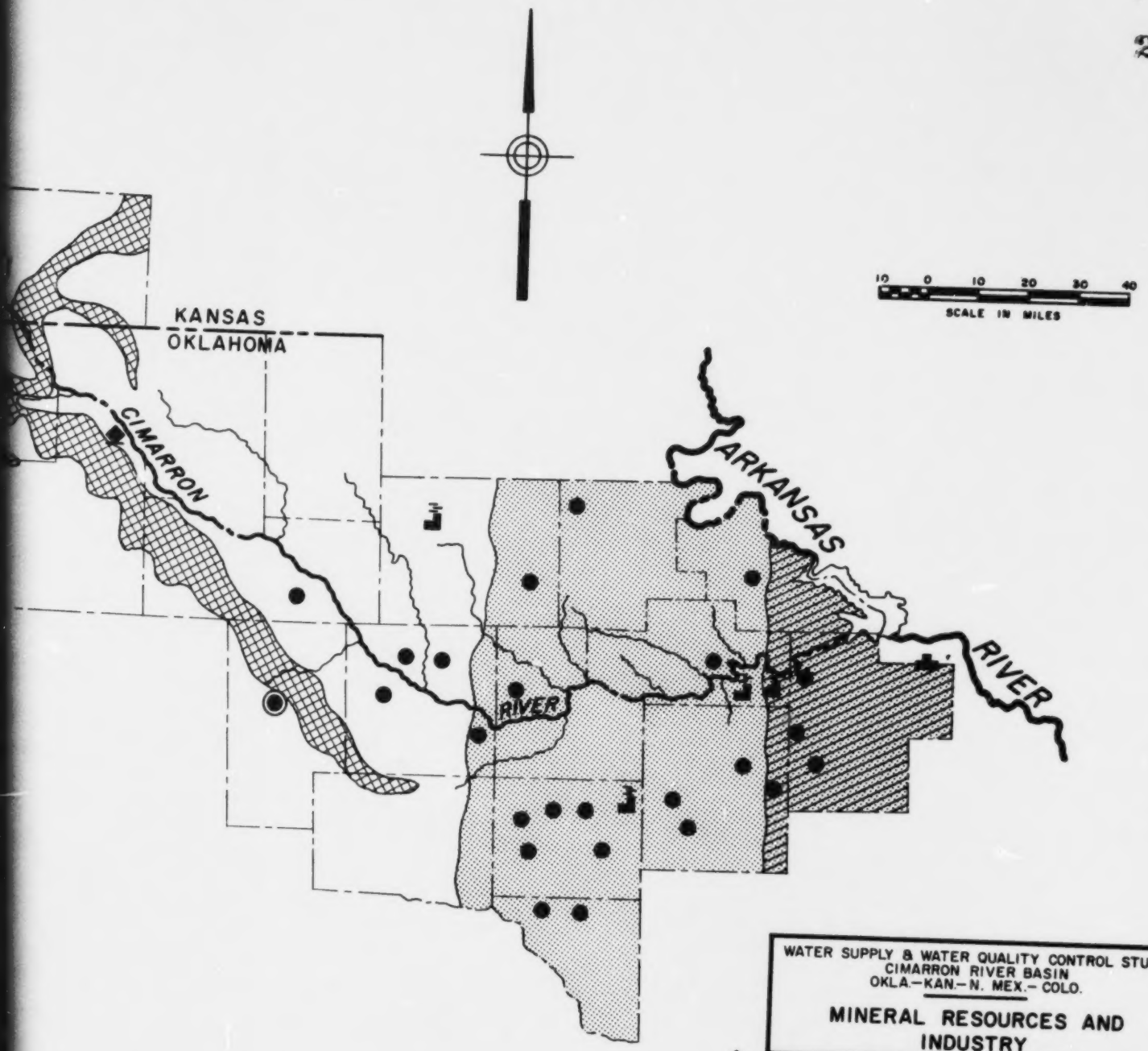


WATER SUPPLY & WATER QUALITY CONTROL STUDY
CIMARRON RIVER BASIN
OKLA.—KAN.—N. MEX.—COLO.

MINERAL RESOURCES AND INDUSTRY

UNITED STATES DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
SOUTH CENTRAL REGION DALLAS, TEXAS

FIGURE 3

Wheat is still the primary crop produced in the area. In recent years, government control of wheat acreage has caused farmers to diversify their farming operations and to put more emphasis on feed grain and livestock production. Within the past 15 years, livestock production has increased almost 75 percent in the study area. With the increase in livestock production sorghum has become increasingly important in the area's crop production. Sorghum is produced on most farms to complement the livestock enterprise. The growth of the grain sorghum industry has caused much of the increase in study area irrigation. Moisture content has been a limiting factor in farm production throughout much of the area due to infrequent and unpredictable rainfall. Sorghums are very responsive to irrigation and, if irrigated properly, will increase their yield per acre several times. Irrigation is practiced throughout Southwestern Kansas and Northwestern Oklahoma where high productive soils will double their yields when adequate moisture is available.

c. Manufacturing - Characteristic of many parts of the western and southwestern states, manufacturing employment in the study area is increasing faster than the national average. The area gained 93 percent in manufacturing employment between 1940 and 1960, while the Nation gained 52 percent. The percentage of the labor force employed in manufacturing is much lower for the study area than for the Nation. Ten and one-half percent of the study area labor force is employed in manufacturing, compared to 24 percent for the Nation. A comparison of manufacturing labor force distribution between the study area and the Nation is shown in Table V-5. As shown by the table, the balance between resource and non-resource oriented manufacturing employment, differs little from the Nation. However, there are considerable differences in the individual industry groups.

The major differences in resource oriented industries is a result of the predominance of oil, gas, and agricultural production in the region, and the lack of metallic mineral resources. This accounts for the higher ratios in food and kindred and other nondurables (primarily gas processing and petroleum refining) and the low ratio in primary metals. In the non-resource oriented industries, employment in textiles and apparel is low in the study area compared to the Nation, while employment in printing and publishing has been greater in the area than in the Nation.

Table V-5

Percentage Distribution of Manufacturing Labor Force for the Nation and the Study Area 1960

	Study Area	United States
Total Manufacturing	100.0	100.0
Resource Oriented	46.2	37.5
Furniture, Lumber, and Wood Products	5.1	7.0
Primary Metals	1.3	7.6
Food and Kindred Products	22.2	11.8
Chemical and Allied Products	2.2	5.2
Other Nondurables	15.4	5.8
Nonresource Oriented	53.8	62.5
Fabricated Metals, Machinery, Transportation and other Durable Goods	39.4	42.0
Textiles and Apparel	2.5	13.5
Printing and Publishing	11.9	7.0

Source: Growth Patterns in Employment by County, U.S. Department of Commerce.

d. Service Industries - Service industries include all establishments not directly engaged in extractives or manufacturing. These industries constitute the largest segment of study area employment and a significant portion of the area's economic activity. Employment in this category was 56 percent of the total labor force in 1940 and 75 percent in 1960. The national increase for the period was from 46 to 63 percent. The majority of the service industry is centered in the lower basin. In 1960, 75 percent (198.2 thousand) of the basin's service industry was located in this region.

B. Future

1. General - In projecting the economic growth of the study area primary consideration was given to trends established over the past 20 years. All facets of the economy which might influence future growth in the area, were investigated. This required: (1) a survey of natural resources or products which might eventually be valuable as raw materials, (2) an evaluation of employment growth, (3) a look at the growth of industry, (agriculture, services, manufacturing, and extraction of raw materials) and, (4) an analysis of population growth.

Several factors will influence future economic development in the study area. Most important will be the area's advantages for meeting a portion of the Nation's future demand for goods and services. These are determined by the availability of raw materials, adequate labor supply, fuel, power, access to markets and the ability and initiative of the people to employ the region's resources. All of these advantages are characteristic of the study area.

2. Population - Population projections for the Cimarron River Basin Study Area were based primarily on growth trends established over the past 50 years. The projections reflect the national trend toward urbanization, and optimistic resources development and employment trends. Growth comparisons were made with cities that were of similar size to the cities of the study area in the past, and historic trends in the ratio of labor force to population were applied to the projected labor force. The projections were made for three geographical subareas which have exhibited similar economic backgrounds and population trends. These subareas were also used in making water use projections. Figure 2 shows the three geographical subareas. Table V-6 contains the projected population for the subareas and the study area.

3. Industry

a. Minerals - The upper reaches of the basin contain large supplies of sandstone, clays and salt that are useful as structural and building materials, industrial and manufacturing materials (wares), refractory and ceramic materials and chemical materials. The middle basin contains

Table V-6

U. S. and Base Study Area Population Projections

	1960 Pop.		2020 Pop.		2070 Pop.	
	Total	Urban	Total	Urban	Total	Urban
Upper Basin	98,876	47,801	240,000	196,000	450,000	416,000
Middle Basin	67,180	14,005	130,000	85,000	190,000	146,000
Lower Basin (without Okla. City SMSA)	219,117	121,124	395,000	350,000	720,000	680,000
Oklahoma City SMSA	502,833	476,691	1,800,000	1,780,000	4,750,000	4,730,000
TOTAL	888,006	659,621	2,565,000	2,411,000	6,110,000	5,972,000
% of U.S.	0.49%		0.64%		0.80%	
1/ U. S.	180,700,000		398,600,000		761,300,000	

Source: 1/ Preliminary Report on Economic Projections for Selected Geographic Areas, U. S. Water Resources Council, March 1968.

supplies of salt, clays and gypsum which can be used to produce wallboard and sulphur. Deposits of pumice and volcanic ash, useful in abrasives and manufacturing and construction materials, also occur in the region. Most of the materials found in the upper and middle basin are also present in the lower basin. Scattered deposits of shale, which is used in building materials, are also found in the area.

The study area is one of the oldest and most productive oil and gas regions in the Nation. These resources have been developed in the study area for over 50 years. Vast oil and gas reserves are still present in the area, but little expansion above the present level of production is expected. New methods of recovery will increase the yield of existing reserves, and with new discoveries the oil and gas deposits will not be depleted for 40 to 50 years.

b. Agriculture - The Cimarron River Basin contains some of the most productive farmland in the Nation and will contribute to the national agricultural growth. Recent declines in study area farm employment, acres of cropland harvested, and number of farms reflect the national trend toward mechanized farming with emphasis on output per acre. This trend is increasing agricultural production.

Livestock grazing and the production of feed grains, hay, and wheat will account for most of the study area's agricultural land use in the future. Increases in output per acre will preclude the need for additional farmlands.

The study area is expected to increase production of meat 3.5 times by 2020. This is slightly greater than the expected national increase.

Wheat production will increase about 30 percent between now and 2020, while dropping in total acreage. It is assumed that future production of wheat will approximate the same relationship to total United States wheat production as the study areas has to total United States crop production over the past 15 years. Because of the predominance of wheat production in past years and the lower starting base, future production of feed grains and

hay in the study area is expected to surpass the national growth rate. Study area feed grain and hay production in 2020 is expected to increase by a factor of 2.6. Production of other farm commodities in the study area is expected to grow at a lesser rate than that projected for the Nation.

c. Manufacturing - Resource-oriented manufacturing industries will be important to the economic growth of the study area. As the agricultural industry expands to meet the Nation's growing needs for food products, new food processing industries are expected to move into the area. Expandsion is also expected in the production of leather goods. Vast reserves of nonmetallic raw materials will encourage growth of several industries in the region. Products that could be produced include manufacturing materials (wares), ceramics, chemicals, sulfur, wallboard, and abrasives. Although petroleum resources will eventually be exhausted, oil and gas product industries will remain a major segment of the study area economy. Most of the study area's gas reserves are committed to eastern markets for fuels. However, future progress in obtaining a high quality gas from eastern coalfields might release the gas for local use; opportunities will then exist for expansion of the petrochemical industry in the region. Large networks of gaslines now running from the study area to eastern and western markets pass through the area's most productive farmlands. Petrochemical plants engaged in the production of chemical fertilizers could locate near these lines, and using natural gas as feedstock, provide a resource and market-oriented fertilizer industry. On this basis, a 2020 production of 1.5 billion pounds per year of petrochemicals for use in fertilizer is projected.

Petroleum refining is also expected to continue as a major industry. As existing crude oil resources are exhausted, new supplies may be obtained from the vast oil shale deposits in the Colorado River Basin by way of the large pipeline network now running from the study area into Colorado. To meet the energy demands projected for the Nation, a twofold increase in production is expected (from about 55,000 barrels per day to 115,000 barrels per day).

As other sources of energy such as nuclear energy and the use of solar heat become more competitive with petroleum, important refinery by-products, which are

now valuable in producing or upgrading fuels, might also become available for use as petrochemical feedstocks. Refinery feedstocks, complemented with feedstock from gas processing plants, could encourage production of synthetic fibers, plastics, and detergents. Approximately 500 million pounds per year of petrochemicals, essential to the production of these commodities, are projected for the study area by the year 2020.

Many of the non-resource oriented industries are engaged in the production of fabricated materials and machinery used in the area's oil and gas, and food and kindred industries. This leaves considerable opportunity in the study area for such industries as electrical equipment, packaging materials, appliances, and miscellaneous household and personal goods.

Nearness of the study area to the geographic center of the Nation could further encourage manufacturing growth in production of nationally marketed goods such as clothing, office machines, optical instruments and electronic instruments. These and other such industries would be well situated in the study area to serve national markets.

Transportation will not be a limiting factor as the study area grows. Interstate highway and rail facilities linking the area with the Nation's population centers are continually being improved. Barge transportation via the Arkansas River will be available within 100 miles to most of the study area's communities and may encourage production of increasingly important bulk commodities such as space air frames, jet engines, industrial machinery rocket motors, and agricultural products.

4. Employment - Total employment in the study area will continue to increase and by 2020 employment should reach 950,000. The service industries, with construction employment included, are expected to continue to be the largest employer in the area. By 2020 service employment is projected to be 768,000 or 78 percent of the total labor force. Manufacturing employment will expand in the study area, and will employ almost 15 percent of the labor force by 2020. As greater use is made of the study area's natural resources, employment in the resource oriented

industries will grow from 16,000 in 1960 to an expected 58,000 in 2020. The opportunities for expansion of the non-resource oriented industries will increase the employment in those industries. Non-resource oriented industrial employment is expected to be almost 88,000 by 2020.

Downward trends in agricultural employment will continue for the next 20 to 30 years as farming continues to become more mechanized. Farm labor will decrease and stabilize at about 21,000 by 2020.

The supply of mineral resources in the study area will increase employment in the extractive industry. Employment declines are expected in the oil and gas extractive industry, but overall employment in mineral production should continue to increase as greater use is made of the nonmetallic mineral resources. An increase of employment from 12,000 in 1960 to approximately 17,000 is projected for the extractive industries by 2020.

Table V-7 shows the projected 2020 employment in the study area.

Table V-7

Projected 2020 Employment in the Study Area

	Employment	Percent Distribution
Agriculture[a/]	20,700	2.1
Mining	16,900	1.7
Manufacturing	145,600	14.8
Resource Oriented	58,100	5.9
Furniture, Lumber and Wood Products	4,200	0.4
Primary Metals	1,000	0.1
Food and Kindred Products	19,300	2.0
Chemical and Allied	17,500	1.8
Other Nondurables	16,100	1.6
Nonresource Oriented	87,500	8.9
Fabricated Metals, etc.[b/]	66,800	6.8
Apparel and Textiles	9,900	1.0
Printing and Publishing	10,800	1.1
Service Industries[c/]	768,000	78.4
Unemployed	29,600	3.0
Labor Force	980,800	100.0

a/ Includes 200 employed in Forestry and Fisheries.
b/ Includes fabricated metals, machinery, electrical equipment, transportation equipment and other durable goods.
c/ Includes construction.

VI. WATER RESOURCES

A. Surface Waters

1. Surface Water Availability - Streamflow in the Cimarron River and its tributaries is generally low and intermittent, particularly in the upper two-thirds of the basin. Rainfall in this area varies from 15 to 25 inches per year, and with the high rate of evaporation and poorly defined drainage, much of the runoff disappears before reaching the river. Flows from Colorado and New Mexico which enter the river, often disappear upon reaching the sandy river channel in Kansas, and never pass the Kansas-Oklahoma State line. A minimum daily flow of 0.8 cfs has been recorded at Perkins, Oklahoma, near the mouth of the river. This is an extremely low flow from a drainage area of 18,000 square miles.

The U.S. Geological Survey presently maintains stream gaging stations at 13 points in the basin. The locations of these stations are shown on Figure 2 and a summary is presented in Table VI-1. As shown on this table all stations with long-term records have experienced zero or near-zero flows. Periods of low or zero flows occur throughout the basin each year particularly during summer and fall months.

Due to the lack of sustained flow in the upper basin, and the mineral quality of the mainstem in the lower basin, there are no major impoundments of water in the Cimarron River Basin. There are, however, several municipal lakes in the study area. Pertinent data for these impoundments are shown on Table VI-2.

2. Surface Water Quality - In the upper reaches of the Cimarron River in New Mexico, the quality of surface water is satisfactory for most uses. Through the western Oklahoma Panhandle, the water contains moderate to high sulfate concentrations. Near Englewood, Kansas, salt springs and seeps from underlying salt beds increase the sodium and chloride content and make the water doubtful for irrigation use. Tributary inflow in this area is also saline. In the vicinity of the Cimarron River's passage from Kansas into Oklahoma, the river and its tributaries are polluted with chlorides from salt springs and from contact with natural salt beds. Throughout Oklahoma, the chloride concentrations are

Table VI-1

Summary of Stream Gaging Stations

Gage No.	Location	Years of Record	Drainage Area (Sq. Miles)	River Mile	Average Discharge (cfs)	Flow Extremes (cfs) Maximum	Minimum
7-1579.6	Buffalo Creek near Lovedale, Oklahoma	1	408	8	14.3	15,800	0
7-1630	Council Creek near Stillwater, Oklahoma	33	31	10	11.1	25,000	0
7-1575	Crooked Creek near Nye, Kansas	25	1,157	14	46.1	13,600	0
7-1605	Skeleton Creek near Lovell, Oklahoma	18	410	15	108	75,200	0
7-1592	Kingfisher Creek near Kingfisher, Oklahoma	1	157	18	39.9	17,600	0
7-1590	Turkey Creek near Drummond, Oklahoma	20	248	22	51.2	18,800	0
7-1610	Cimarron River at Perkins, Oklahoma	28	17,852	87	1,177	149,000	0.8
7-1600	Cimarron River near Guthrie, Oklahoma	30	16,892	122	897	158,000	0.1
7-1580	Cimarron River near Waynoka, Oklahoma	30	13,334	247	382	94,500	0
7-1579.5	Cimarron River near Buffalo, Oklahoma	7	11,930	296	145	9,280	0
7-1569	Cimarron River near Forgan, Oklahoma	2	8,536	376	122	21,200	35
7-1545	Cimarron River near Kenton, Oklahoma	17	1,106	594	38.1	43,400	0
7-1535	Cimarron River near Guy, New Mexico	25	545	621	11.8	46,100	0

Source: Water Resources Data for Oklahoma, 1967, U.S. Geological Survey.

Table VI-2

Existing Surface Water Supply Developments in the Study Area

State	County	Municipality Served	Reservoir	Total Capacity (Acre-ft.)	Yield (mgd)
Colorado	Las Animas	Trinidad	Monument Lake	N.A.	8.00
New Mex.	Colfax	Raton	Lake Maloya*	N.A.	4.00
Oklahoma	Lincoln	Chandler	Chandler City Lake*	2,500	.67
			S.C.S.*	25,000	3.75
	Creek	Sapulpa	Lake Sahoma*	4,850	1.9 1/
			Sapulpa Lake*	800	N.A.
			Low Water Dam*	40	N.A.
			Pretty Water Lake*	80	N.A.
	Pawnee	Pawnee	NWNE 32-22N-5E*	N.A.	0.05 1/
			NENE 31-22N-5E*	N.A.	0.07 1/
			30-22N-5E*	3,855	0.22 1/
	Cleveland	Cleveland	Cleveland Lake	2,212	0.23 1/
	Payne	Cushing	Cushing Lake	4,576	2.02 1/
	Logan	Guthrie	Guthrie Lake	2,246	0.65 2/
			Liberty Lake	2,814	0.28 2/
			Unnamed SCS # 57	2,233	0.82 2/
	Noble	Perry	Perry Lake*	4,137	0.65 1/
	Payne	Stillwater	Carl Blackwell	55,000	4.29 1/
			Boomer Lake	2,486	0.10 1/
			McMurtry Lake	13,350	2.70 3/
	Oklahoma	Okla. City	Lake Overholser*	15,000	6.26
			Lake Hefner*	76,000	15.02

* Source of Supply not in Cimarron Basin

1/ 1968 Reported Water Use.
2/ Guthrie has three lakes on Cottonwood Creek Tributaries and to supplement their natural runoff a pump station on Cottonwood Creek to fill these three lakes. There is also an interchange system between these lakes so their actual yield is not available. These figures are as reported for 1968 by the City of Guthrie.
3/ Under construction.

Source: Colorado and New Mexico - Municipal Water Facilities, 1963 Inventory, Public Health Service.
Oklahoma - Oklahoma Water Resources Board.

such that the waters of the river are unsatisfactory for almost all uses. At the Perkins gage in the lower Cimarron River, the average daily concentrations of chlorides is 1,700 mg/l, with daily maximums in excess of 4,000 mg/l. These concentrations contribute approximately 70 percent of the chloride load of the Arkansas River. In 1964, the Public Health Service completed a study of the natural salt pollution of the Arkansas and Red River Basins, including the Cimarron River Basin. The results of this study are discussed in Chapter VII and Chapter IX.

3. Surface Water Use - The use of surface water in the Cimarron River Basin is limited by the lack of sustained flows in the upper basin and poor mineral quality of the mainstem in the lower basin. Three urban areas in the basin, see Table VI-3, use water from tributaries of the Cimarron River for municipal water supplies. Lake Hefner (Oklahoma City's water supply reservoir) is located within the basin, but is used for pumped storage of North Canadian River flood flows, and is not Cimarron River Basin water.

Table VI-3

Municipal Surface Water Supply Use
(Million gallons per day)

City	Average Daily Use	Basin of Supply
Trinidad 1/	3.25	Purgatoire River
Raton 1/	0.87	Canadian River
Chandler 2/	4.42	Canadian River
Cleveland	0.23	Trib. to Arkansas River
Cushing 2/	2.02	Trib. to Cimarron River
Guthrie 2/	1.75	Trib. to Cimarron River
Oklahoma City 1/	33.2	North Canadian R. & Others
Pawnee 2/	0.34	Trib. to Arkansas River
Perry 2/	0.65	Trib. to Arkansas River
Stillwater 2/	4.39	Trib. to Cimarron River
Sapulpa 1/	0.9	Trib. to Arkansas River

Source: 1/ Municipal Water Facilities, U.S. Department of Health, Education, and Welfare, 1963 Inventory.
2/ Oklahoma Water Resources Board.

Industrial use of surface water, primarily in the petroleum and natural gas industries, amounts to approximately 17 mgd, 90 percent of which is centered in the Oklahoma City SMSA and taken from streams outside of the Cimarron River Basin.

Approximately 15 mgd is currently used throughout the basin for irrigation, most of which is taken from the Cimarron River above the salt plains.

B. Ground Water

1. Ground Water Availability - Large supplies of good quality ground water are available throughout the basin, particularly in the dry basin areas of Kansas and Oklahoma. In the Colorado and New Mexico portion of the upper basin, there is a small area of ground water occurrence. Wells from rocks of the Triassic and Jurassic age supply fresh water, with yields approximately 300 gpm. In the Kansas portion of the basin, the major source of ground water is the Pliocene and Pleistocene Rocks, which include the Ogallala formation. Wells in this area yield up to 1,000 gpm and are the chief source of supply for domestic, municipal, irrigation, and industrial water. Below the Kansas-Oklahoma State line, ground water in the study area can be obtained from: (1) deposits of the high plains; (2) alluvial deposits; and (3) sandstone aquifers (central Oklahoma). Wells in the high plains and alluvial deposits yield from 100 gpm to 1,000 gpm. Yields of 100 gpm from wells 300 to 550 feet deep are used for municipal and industrial needs at Cushing and Drumright, Oklahoma. Wells in the Oklahoma City area penetrating 400 to 750 feet of shale and sandstone yield 100 gpm to 250 gpm.

The total annual recharge for aquifers within the study area is about 860,000 acre-feet. For most of the study area, recharge over a long period of time is sufficient to replace withdrawals. However, withdrawal from the large Ogallala aquifer in the heavily irrigated portion of southwestern Kansas has exceeded the estimated annual recharge. In the surficial aquifers beneath the High Plains area of Kansas and western Oklahoma, approximately 112 million acre-feet of water is in storage. In the remaining lower half of the basin, almost 9 million acre-feet of water is in storage.

2. Ground Water Quality - Ground water from the High Plains deposits is good quality and is rated good to excellent for irrigation. The water contains 200 to 500 ppm of dissolved solids and has a hardness between 150 and 300 ppm. The water is used for municipal supply without treatment, other than chlorination. Most residents use home water softeners to reduce the hardness.

Water in the unconsolidated sediments beneath the terraces and flood plains is more highly mineralized than water in the High Plains sediments. Ground water withdrawn from the unconsolidated sediment is satisfactory for irrigation, but is treated prior to municipal use.

Table VI-4 shows the quality of the ground water used by municipalities in the study area.

Table VI-4

Municipal Ground Water Quality
(Concentration in mg/l)

			Hardness					
Municipality	pH	Na	NCH	Total	Ca	Cl	SO_4	TDS
Hugoton, Kansas	7.7	39	139	325	71	18	179	494
Liberal, Kansas	7.4	26	54	234	61	19	76	362
Ulysses, Kansas	7.7	46	148	320	69	22	207	527
Woodward, Okla.	7.3	18	21	107	34	26	23	197
Alva, Oklahoma	7.6	13	0	134	44	8	11	197
Enid, Oklahoma	7.3	72	0	182	48	60	26	379
Kingfisher, Okla.	7.9	96	0	272	73	66	87	543

Source: 1/ Chemical Quality of Public Water Supplies in Kansas, Nov. 1968, Kansas State Dept. of Health.
2/ Public Water Supplies in Oklahoma, U.S. Geological Survey.

3. Ground Water Use - Ground water is used throughout the basin for municipal, industrial, and irrigation purposes. The rural communities and most of the urban areas depend on ground water to serve their water demands. Table VI-5 shows the current ground water use of major communities in the study area, and the estimated yield of their well systems. Current usage includes industrial demands served by the municipal systems.

The major use of ground water in the basin is for irrigation. In 1965, approximately 680,000 acres of land were irrigated. This includes 15,000 acres in New Mexico, 30,000 in Colorado, 445,000 acres in Kansas, and 190,000 acres in Oklahoma. Total water applied in 1965 was approximately 775,000 acre-feet (690 mgd). The growth of irrigation in the study area in recent years has been phenomenal. Table VI-6 is a summary of the growth of irrigation in Kan Kansas from 1950 to 1965. The only deterrent to continued rapid growth would be a depletion of the ground water supply.

The majority of industries in the basin, involved in the extraction and processing of natural gas and petroleum, obtain their water supplies from municipal systems. In several locations, due to the lack of water, treated municipal effluents are used by industries for cooling purposes. Industrial use of ground water from private well systems currently is approximately seven million gallons per day.

Table VI-5

Municipal Groundwater Supplies in the Study Area

State	Municipality	Present Water Use (mgd)	2/ Est. Yield (mgd)	No. Wells
New Mexico	1/ Clayton	0.60	1.25	7
Kansas	Ulysses	0.66	3.02	Several
	Hugoton	0.75	2.90	Several
	Liberal	2.90	4.50	14
Oklahoma	1/ Guymon	0.90	4.90	8
	1/ Alva	1.0	3.25	18
	1/ Woodward	1.2	5.20	36
	Enid	4.6	29.0	84
	Kingfisher	0.2	4.32	5
	1/ Yukon	0.6	6.0	13
	1/ Norman	3.0	3.8	22
	1/ Bristow	0.25	0.82	19
	Drumright	0.45	1.50	10
	Cushing	1.3	2.98	9
	1/ El Reno	1.5	4.50	14
	Watonga	0.6	3.0	6
	Bethany	1.5	6.0	11
	1/ Del City	1.8	2.85	15
	Edmond	1.56	4.0	10
	1/ Midwest City	3.5	5.0	35
	1/ Nichols Hills	1.0	4.5	20
	Oklahoma City	3/ Varies	30.0	105

1/ Not in Cimarron River Basin

2/ Indicates yield of present well system, not necessarily aquifer yield.

3/ Groundwater used only when needed to augment surface supplies.

Source: Municipal Water Facilities, 1963 Inventory, Public Health Service.

Table VI-6

Growth of Irrigation in the Cimarron Basin, Kansas

Year	Acres Irrigated	Average Rate of Application (Acre-Feet Per Acre)	Total Water Applied (Acre-Feet)
1950	35,290	1.70	60,000
1951	41,310	1.75	72,300
1952	47,840	1.94	92,700
1953	58,240	2.00	116,300
1954	92,450	1.98	183,300
1955	159,840	2.10	335,700
1956	222,320	2.51	558,200
1957	251,610	2.05	515,000
1958	275,500	1.74	480,500
1959	310,800	1.71	532,300
1960	311,800	1.70	530,900
1961	319,800	1.76	563,900
1962	336,400	1.81	610,500
1963	345,200	2.06	712,700
1964	381,100	2.33	887,200
1965	446,100	1.52	679,100

Source: Groundwater in the Cimarron River Basin, Sept. 1966, U.S. Geological Survey.

VII. WATER QUALITY PROBLEMS

A. Natural Salt Pollution

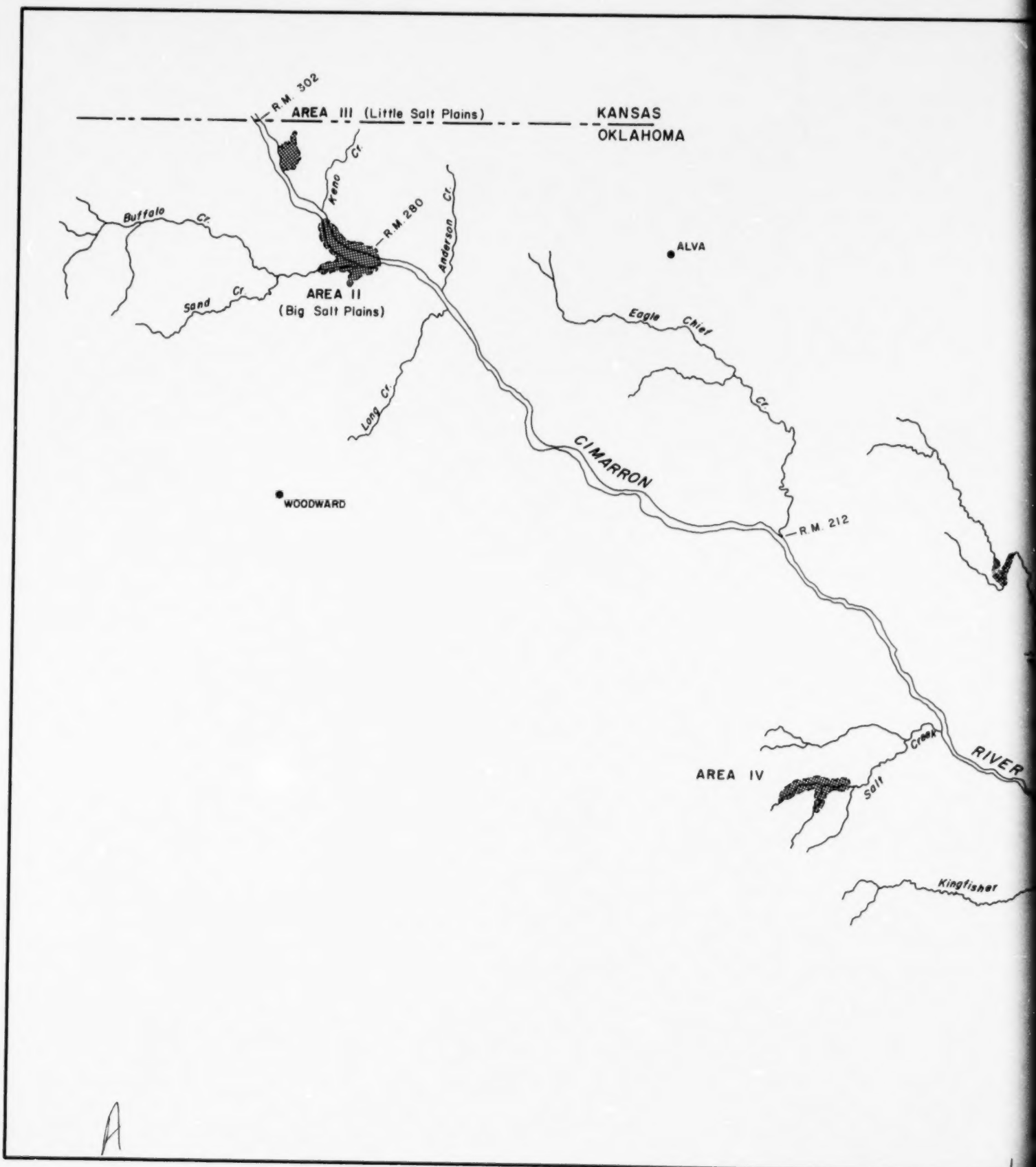
1. General - The primary pollution problems in the basin are the natural salt plains south of the Kansas-Oklahoma border which render the lower Cimarron River unusable for practically all purposes. In 1964, the Public Health Service completed an extensive study of the natural salt pollution in the Arkansas and Red River Basins, including the Cimarron River Basin. The following paragraphs are a description of the salt pollution in the Cimarron Basin, taken from the 1964 Public Health Service Report entitled, "Arkansas-Red River Basins, Water Quality Conservation." Figure 4 shows the locations of the salt sources.

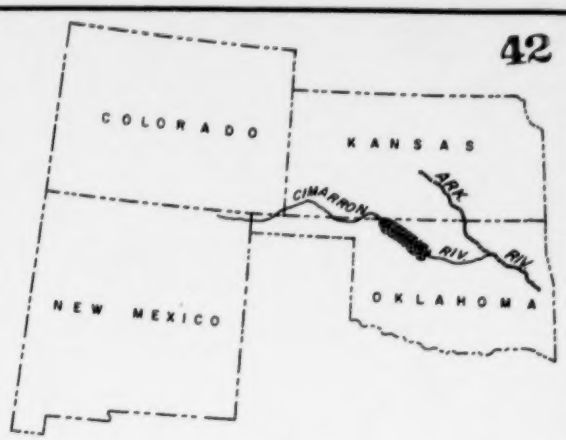
2. Big Salt Plains of the Cimarron River -

The Big Salt Plains are a broad flat, alluvial surface that occupies the flood plain of the Cimarron River. The floor of the plain is encrusted with crystallized salt of varying thickness.

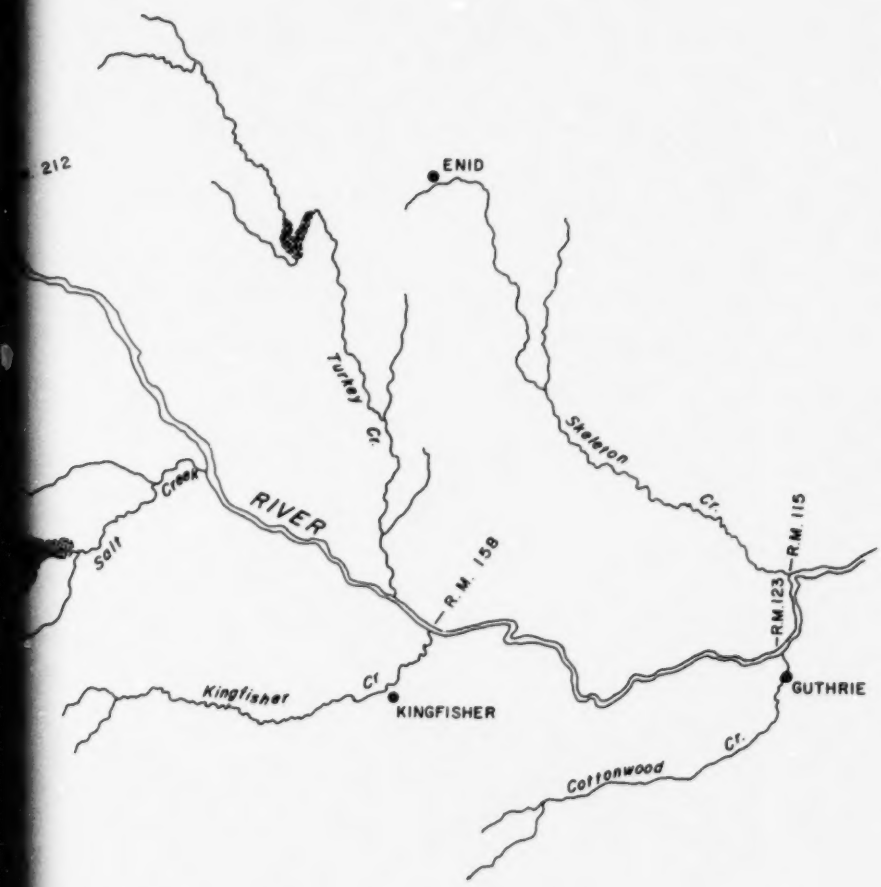
This salt plain includes about eight square miles of the flood plain of the Cimarron River in parts of Woods, Woodward, and Harper counties, Oklahoma.

Small springs and seeps of saturated brine (containing about 26 percent NaCl) occur along the northern and southern margins of the plains and along the banks of Buffalo and Elm Creek canyons. Evaporation of these brines during periods of dry weather causes salt to accumulate on the surface of the plain. Deposits of salt up to three or four inches in thickness have been observed at the confluence of Buffalo and Elm Creeks. Accumulation of solid salt on the flood plain can amount to 125,000 tons during periods of dry weather. In addition to the salt crust, the alluvium is saturated with brine waters of varying salt concentration. Samples of brines taken in the alluvium at the lower end of the Big Salt Plains, between Sand and Moccasin Creeks, show an increase in concentrations with depth.


R.M. 302
AREA III (Little Salt Plains)
KANSAS
OKLAHOMA
Keno Cr.
Buffalo Cr.
R.M. 280
Anderson Cr.
ALVA
AREA II
(Big Salt Plains)
Sand Cr.
Eagle Chief Cr.
Long Cr.
CIMARRON
WOODWARD
R.M. 212
Salt Creek
RIVER
AREA IV
Kingfisher



VICINITY MAP



WATER SUPPLY & WATER QUALITY CONTROL STUDY
CIMARRON RIVER BASIN
OKLAHOMA – KANSAS – NEW MEXICO – COLORADO

SALT SOURCES

UNITED STATES DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
SOUTH CENTRAL REGION DALLAS, TEXAS

FIGURE 4

The chloride contribution from springs in the area is estimated at 1,600 tons per day. The visible salt springs do not account for the total salt load contributed to the river in the salt plain area. The additional load is added by salt water seeping from the bedrock directly into the overlying alluvial sand.

The chloride and sulfate pollution load of the Cimarron River from this area has been interpolated from the results obtained from a water monitoring station a short distance below the plain.

This shows an influx of about 110 cubic feet per second and results in a load increase to the river of 2,950 tons per day of chloride and 75 tons per day of sulfate. An analysis of the area water is given on Table VII-1.

3. Little Salt Plains of the Cimarron River -

The Little Salt Plains are approximately two square miles in area and include parts of Harper and Woods counties in Oklahoma about two miles south of the Kansas border. The plain is located near river mile 298 of the Cimarron River upstream from Big Salt Plains as shown on Figure 4.

The Little Salt Plains are on the Quaternary alluvium of the river bed and has as its bedrock the Flowerpot Shale. This formation also is exposed on the cliffs which border the river. The upper part of these cliffs and caprock is composed of the Blaine formation. Farther away from the river, the Dog Creek Shale and Whitehorse Group cap the higher ridges. Salt encrustations are visible in the outcropping shale several feet below the base of the overlying Blaine gypsum. The rock sequences and their lithologic character are essentially the same as in the Big Salt Plain but only the upper 20 to 30 feet of the Flowerpot Shale is exposed in the Little Salt Plains area.

Table VII-1

Chemical Analyses of Natural Brines, Big Salt Plains of the Cimarron River

	Collection Point				
	Groundwater Sample 2.5' Deep Near Blackmon's Ranch	Brine Spring South Bank of Buffalo Creek	Blackmon's Brine Well 500' SW of House	Blackmon's Brine Well 1,000' WSW of House	Blackmon's Brine Well ½ Mile SE of House
Date Collected	9-13-60	5-19-60	5-26-60	5-26-60	5-26-60
pH	7.3	6.9	5.6	4.1	4.1
Specific Gravity, 20°C	1.2132	1.1953	1.1930	1.1685	1.1944
Spec. cond. 25°C, micromhos/cm		210,000	210,000	220,000	220,000
Total alkalinity ($CaCO_3$)	28	30	20	20	20
Total hardness ($CaCO_3$)	7,200	8,000	6,400	7,200	6,800
Dissolved Solids	313,500	317,800	318,400	276,700	320,300
Calcium (Ca)	1,520	1,440	1,440	1,840	1,200
Magnesium (Mg)	825	1,070	680	630	925
Sodium (Na)	118,800	110,000	108,000	103,000	110,000
Potassium (K)	140	2,230	200	170	230
Sulfate (SO_4)	3,500	4,950	4,500	3,800	4,500
Chloride (Cl)	189,000	189,500	189,000	159,000	189,000
Iron (Fe)	0.10	0	Trace	62.5	3.2
Silica (SiO_2)		3.4	1.8	1.8	0.08
Boron (B)	2.0	1.7	1.6	4.7	
Fluoride (F)	2.8	3.2	2.0	0.5	2.0
Iodine (I)					
Bromine (Br)	20	20	20	20	20
Manganese (Mn)		0	Trace	1.8	0.1

All chemical analyses expressed as mg/l, except pH, unless otherwise indicated.

Source: "Arkansas-Red River Basins Water Quality Conservation", Public Health Service, June 1964.

The alluvial fill in the Cimarron River valley ranges up to 80 feet in thickness in this area and is saturated with brine waters of varying chloride concentration. Salt springs have not been observed at Little Salt Plains, but small seeps were observed. Salt water moves toward the river from both sides. The dune sand and terrace deposits on the north side and the fractured shale and gypsum on the south side facilitate the downward flow of groundwater to the Salt-bearing strata and then into the alluvium.

Both chloride and sulfate concentrations increase with depth in the alluvium. In addition to storage of brine in the alluvium, salt accumulates in a crust-like layer on the surface of the plain.

The Cimarron River pollution load from this area, is about 600 tons per day chloride and 20 tons per day sulfate. Analyses of the area water are given on Table VII-2.

4. Salt Creek of the Cimarron River -

Salt Creek enters the Cimarron River about nine miles east of Okeene, Oklahoma, at about river mile 179. From this point in Kingfisher county, the creek extends in a southwesterly direction approximately 20 miles to its source in Blaine county.

Salt Creek has its source along the base of a steep, eastward-facing escarpment that is capped by Dog Creek Shale and the Blaine Formation, and is underlain by the Flowerpot Shale. All three of these major formations of the El Reno Group are suspected salt bearers. The Flowerpot has a thickness of up to 450 feet in this area; the Blaine ranges from 75 to 100 feet in thickness; and the Dog Creek Shale is from 160 to 190 feet feet thick. The bedrock of Salt Creek is the Flowerpot Shale in the area

Table VII-2

Chemical Analyses of Natural Brines,
Little Salt Plains of the Cimarron River

	Collection Point	
	Brine Seep on East Side of Salt Plain Sec. 25 T29N, R21W, Woods Co.	Shallow Ground Water - Less than 3' in Depth
Date Collected	11-17-59	1-6-60
pH	6.7	7.2
Specific Gravity, 20°C	1.204	1.0636
Spec. cond. 25°C, micromhos/cm	215,000	125,000
Total alkalinity ($CaCO_3$)		284
Total hardness ($CaCO_3$)	7,570	4,000
Dissolved Solids		107,500
Calcium (Ca)	1,540	1,040
Magnesium (Mg)	910	340
Sodium (Na)	125,000	42,500
Potassium (K)		95
Sulfate (SO_4)	4,560	1,440
Chloride (Cl)	194,000	61,000
Iron (Fe)		0.12
Silica (SiO_2)	2.5	14.6
Boron (B)	2.0	1.0
Fluoride (F)		0.9
Iodine (I)		0.2
Bromine (Br)		10
Manganese (Mn)		

All chemical analyses expressed as mg/l, except pH, unless otherwise indicated.

Source: " Arkansas-Red River Basins Water Quality Conservation", Public Health Service, June 1964.

of pollution and the Cedar Hill member of the Hennessey Shale in the lower part of the stream system. The United States Gypsum Company operates a plant at the head of Salt Creek Canyon, utilizing the Nescatungs and Shimer members of the Blaine Formation which are about 98 percent calcium sulfate.

Ground water movement is up the regional dip, and toward the Salt Creek and Cimarron River valleys. One feature of the drainage between the North Canadian and Cimarron Rivers is the pattern produced by ephemeral and intermittent streams that do not reach the main rivers. Most of these streams are less than a mile long and end in a small sink or depression as an ephemeral lake. Sinkholes have developed in historic time in this region, probably due to solution of the underlying Blaine Formation.

Streamflow originates from fresh surface runoff and wet weather springs, mainly in the overlying gravel and sand deposits that cover the uplands to the west. These deposits act as an aquifer, supplying water to the formations below, where the soluble salts of the Permian formation are taken into solution. Small salt water springs and seeps emerge from all levels of the escarpment in the canyons of the upper three miles of the system and then merge to form Salt Creek. The saline waters saturate the alluvium and, upon evaporation, form a large area of veneered crusts of salt known locally as the Ferguson Salt Plain.

Salt water seeping out of the escarpment raises the chloride ion content in the creek from a few to 10,000 mg/l or more, depending upon the volume of fresh water flowing from higher elevations. An average load of 220 tons per day of chloride and 10 tons per day of sulfate has been measured from this area. Approximately 50 tons of chlorides originate

in each of the north and south main canyons, and the remainder comes directly by subsurface seepage into the streambed proper. Analyses of the water is given in Table VII-3.

5. Turkey Creek of the Cimarron River -

Turkey Creek rises in southern Alfalfa county, Oklahoma near Helena and flows through Garfield and Kingfisher counties, entering the Cimarron River at river mile 162 near Dover, Oklahoma.

The area of salt pollution is an abandoned lakebed through which the stream flows. The ancient lakebed, known locally as Drummond Flat, is in western Garfield county. The abandoned lakebed covers about 12 square miles and is of probably Pleistocene age. The creek flows through Quarternary dune sand and lacustrine deposits which are underlain by the Cedar Hills Member of the Hennessey Shale. Turkey Creek meanders through this bottom land and provides the only means of drainage from the area. One tributary within the bottom land has intermittent flow and contains a light salt crust during dry weather. Salt water is reported at a depth of less than five feet beneath the central portion of the basin.

Water samples were collected about four miles below Drummond Flat by the Geological Survey at intervals from 1951 to 1959. The chloride content of the samples ranged from a few to 2,790 mg/l, and the chloride load averaged about 50 tons per day.

Table VII-3

Chemical Analyses of Natural Brines
Salt Creek of the Cimarron River

	Collection Point		
	Salt Creek North Canyon	Salt Creek Just Above Spring Creek	Salt Creek Spring at Head of North Canyon
Date Collected	11-16-59	11-16-59	8-15-60
pH	7.4	7.9	7.1
Specific Gravity, 20°C	1.102	1.009	1.0718
Spec. cond. 25°C, micromhos/cm	159,000	23,100	124,000
Total alkalinity ($CaCO_3$)			40
Total hardness ($CaCO_3$)	7,200	2,180	6,000
Dissolved Solids			107,000
Calcium (Ca)	1,870	666	1,760
Magnesium (Mg)	636	126	390
Sodium (Na)	57,300	4,650	37,000
Potassium (K)			100
Sulfate (SO_4)	3,520	1,770	5,600
Chloride (Cl)	90,800	7,280	63,500
Iron (Fe)			Trace
Silica (SiO_2)	4.0	6.5	7.2
Boron (B)	2.5	1.3	
Fluoride (F)			3.4
Iodine (I)			3.4
Bromine (Br)			
Manganese (Mn)			34
			0

All chemical analyses expressed as mg/l, except pH, unless otherwise indicated.

Source: "Arkansas-Red River Basins Water Quality Conservation", Public Health Service, June 1964.

B. Municipal and Industrial Waste Returns

Municipal and industrial waste returns in the basin do not create problems due to the lack of heavy population concentrations and large industrial water users. Natural mineral concentration in waste returns generally are lower than the receiving waters, and in the lower mainstem, the return flows usually improve the mineral quality of the river.

The only stream presently affected by municipal waste returns is Cottonwood Creek in the lower basin (see Figure 2). This stream receives the treated wastes from several Oklahoma City suburbs plus a small portion of Oklahoma City's effluent. Despite secondary treatment of all wastes discharged to the stream, during periods of low flows the dissolved oxygen concentration in Cottonwood Creek approaches zero and odors produced by anaerobic conditions have been detected in the creek. This has been of particular concern to the City of Guthrie, as it pumps the high flows of Cottonwood Creek into Liberty Lake for use as a supplementary public water supply. Water samples taken from Liberty Lake have shown that the water stored in the lake is satisfactory and safe for municipal and industrial use.

Table VII-4 is a summary of sewage treatment facilities serving the urban areas of the basin.

C. Irrigation Return Flows - Oil Field Discharges

Return flows from irrigation are not a serious pollution problem due to the high mineral background concentrations of the surface waters. A large percentage of the return flows are lost to the sandy river channels or to the atmosphere as a result of the extremely high evaporation rate.

The brine discharges from oil field operations in Oklahoma have been a problem in the past. These discharges were stored in open earth pits and eventually seeped into the groundwater aquifers, polluting municipal groundwater sources. These pits have been eliminated and brines are now being disposed of by injection into the lower geologic formations. The state pollution control agencies in Oklahoma are regulating the disposal of these oil field brines to insure the protection of groundwater aquifers.

Table VII-4

Municipal Treatment Facilities

City	Treatment	Average Daily Flow (mgd)	Design Flow (mgd)	Receiving Stream
Oklahoma				
Aline	Lagoon	0.02	0.04	Eagle Chief Creek
Ames	"	0.017	0.03	Hayle Creek
Bethany & Warr Acres	"	2.6	4.5	Cottonwood Creek
Buffalo	"	N.A.	N.A.	Buffalo Creek
Carmen	Lagoon	0.03	0.09	Eagle Chief Creek
Cashion	"	0.013	0.045	Cottonwood Creek
Cleo Springs	"	0.018	0.040	Eagle Chief Creek
Coyle	"	0.015	0.040	Cimarron River
Crescent	Tr.Filter	0.10	0.110	Wolf Creek
Cushing - Northside	"	0.70	2.00	Euchee Creek
Cushing - Southside	Lagoon	N.A.	N.A.	Euchee Creek
Dacoma	"	N.A.	0.05	Eagle Chief Creek
Drummond	"	N.A.	0.08	Turkey Creek
Drumright	Tr.Filter	N.A.	0.65	Tiger Creek
Edmond - Eastside	"	0.125	0.15	Spring Creek
Edmond - Northwest	"	0.40	0.50	Chisolm Creek
Enid	Act.Sludge	3.0	5.0	Skeleton Creek
Fairview	Tr.Filter	N.A.	0.25	Sand Creek
Freedom	Lagoon	0.020	0.040	Cimarron River
Gate	"	N.A.	0.03	Beaver Creek
Goltry	"	N.A.	0.047	Turkey Creek
Guthrie	Tr.Filter	0.60	1.00	Cottonwood Creek
Helena	Lagoon	0.024	0.060	Turkey Creek
Hennessey	"	N.A.	0.170	Turkey Creek
Jennings	Sep.Tank	N.A.	N.A.	House Creek
Kingfisher	Lagoon	N.A.	0.460	Kingfisher Creek
Lahoma	"	N.A.	N.A.	
Langston	Tr.Filter	N.A.	0.05	Fitzgerals Creek
Manneford	Lagoon	0.045	0.150	Salt Creek
Marshall	"	0.030	0.100	Horse Creek
Meno	"	0.007	0.020	Hoyle Creek
Mulhall	"	N.A.	0.020	Beaver Creek
North Enid	Lagoon	N.A.	0.060	
Oilton	"	0.063	0.100	Cimarron River
Okarche	"	0.04	0.120	Uncle John Creek
Okeene	"	N.A.	0.05	Spring Creek
Orlando	"	N.A.	0.040	Beaver Creek

Table VII-4 (Continued)

City	Treatment	Average Daily Flow (mgd)	Design Flow (mgd)	Receiving Stream
Oklahoma (Continued)				
Perkins	Tr.Filter	0.125	0.25	Cimarron River
Ringwood	Lagoon	0.018	0.036	Indian Creek
Ripley	"	0.02	0.040	Cimarron River
Southard	"	0.025	0.030	Salt Creek
Stillwater	Tr.Filter	3.0	4.0	Stillwater Creek
Tryon	Lagoon	0.012	0.030	Sand Creek
Tyrone	"	0.02	0.065	Small Creek
Waukomis	"	0.013	0.086	Turkey Creek
Waynoka	"	0.106	0.150	Dog Creek
Yale	"	0.10	0.120	Mud Creek
Kansas				
Ashland	Tr.Filter	0.110	0.130	Bear Creek
Copeland	Lagoon	0.030	0.040	Crooked Creek
Elkhart	"	0.270	0.280	Evaporation Ponds
Englewood	"	0.030	0.050	Cimarron River
Fowler	Tr.Filter	0.08	0.1	Crooked Creek
Hugoton	Lagoon	0.240	0.360	Pond
Johnson	"	N.A.	0.100	Pond
Kismet	"	0.012	0.014	Cimarron Creek
Liberal	Tr.Fil&Lag.	0.450	1.500	Lagoon
Meade	Tr.Filter	0.180	0.250	Crooked Creek
Minneola	Tr.Fil&Lag.	0.070	0.100	Buff Creek
Moscow	Lagoon	0.030	0.050	Cimarron River
Plains	Tr.Filter	0.080	0.100	Drainage Ditch
Protection	"	0.070	0.080	West Cavalry Creek
Rolla	Lagoon	0.040	0.060	Cimarron River
Satanta	Tr.Filter	1.1	0.08	Cimarron River
Sublette	Lagoon	N.A.	0.204	Seepage Pond
Ulysses	Tr.Filter	0.340	0.400	Cimarron River
Ulysses	Lagoon	N.A.	0.200	Cimarron River
Colorado				
Walsh	Lagoon	N.A.	0.052	Lagoon & Irrigation
Springfield	"	N.A.	N.A.	Bear Creek & Land

VIII. FUTURE WATER SUPPLY DEMANDS AND NEEDS

A. Future Water Supply Demands

1. Municipal - Future municipal water supply demands (Table VIII-1) were determined by applying a per capita water use factor in gallons per capita per day (gpcd) to the projected population (Table V-6) to be be served by municipal water systems. The per capita water use includes such uses as home cooking and cleaning, sanitation, lawn watering, fire demand, and small industries using the municipal systems. It does not include any major industrial use. Per capita water use varies from region to region depending on the municipal population size, price of water, rainfall, climate, and aridity. Of these factors, rainfall has the most affect on water use, therefore, it was used to determine the unit use for the study area. Based on rainfall records, and observed per capita consumption in the study area, a unit water demand of 205 gpcd in the western portion of the basin, and 190 gpcd in the eastern portion was projected for the year 2020. Per capita use through the year 2070 is expected to remain at about the same level as projected for the year 2020.

Table VIII-1

Municipal Water Supply Demands

Subarea	2020 Use (mgd)	2070 Use (mgd)
Upper Basin	40	85
Middle Basin	17	29
Lower Basin (without Oklahoma City)	67	129
Oklahoma SMSA	340	900
Totals	464	1,143

2. Industrial - Industrial water use is dependent on the size and type of industrial plant and the conservation measures practiced by the plant. The industrial water demands in the Cimarron River Basin were developed from the economic projections presented in Chapter V and the industrial demands contained in the 1964 Public Health Service report, "Arkansas-Red River Basins, Water Quality Conservation." Industrial needs beyond the year 2020 are

not projected to increase significantly due to expected process changes employing water reuse and conservation practices. Thermal electric use is projected to decrease and electric power needs of the Cimarron Basin are expected to be met by power networks served by nuclear power plants located outside of the basin.

Table VIII-2 shows the 2020 industrial water requirements. The locations designated are a general area of demand, since it is impossible to predict the exact locations of specific industries.

Table VIII-2

2020 Industrial Water Requirements

Industry	Area	Requirement (mgd)
Petroleum Refining	Enid, Oklahoma	13
	Cushing, Oklahoma	21
	Sapulpa, Oklahoma	12
Petrochemical	Sapulpa, Oklahoma	5
Food and Kindred	Enid, Oklahoma	1
	Oklahoma City, Oklahoma	2
Gas Processing	Liberal, Kansas	2
	Ulysses, Kansas	4
	Oklahoma City, Oklahoma	1
Therma-electric	Stillwater, Oklahoma	5
	Liberal, Kansas	2
	Raton, New Mexico	2
	Oklahoma City, Oklahoma	80

3. Irrigation - The rate of increase in irrigated acreage and water used for irrigation will depend on the availability of water, and the extent of potentially irrigable acreage. Approximately 685,000 acres are currently being irrigated in the Cimarron River Basin, most of which is in the Kansas portion of the basin. An additional 1,250,000 acres of land is suitable

for irrigation in Kansas. Irrigation of this land would require 2,000,000 acre-feet per year (1,780 mgd) of water, which is not available in the basin from either surface or ground water supplies. Any extensive growth of irrigation will require transfer of water from other basins. Without such a transfer, the available ground water and surface water supplies in the upper portion of the study area, will limit the growth of irrigation.

B. Future Water Supply Needs

1. General - Water supply projections (Table VIII-1) were disaggregated in order to identify localities where future demands may exceed available supplies, thus locating specific areas where further development of the surface water resources in the Cimarron River Basin might be needed. Several areas which will need additional sources of municipal and industrial water are described in the following paragraphs.

a. Oklahoma City SMSA - If the Oklahoma City SMSA reaches the level of growth projected, new sources of municipal and industrial water supply will be required to meet its needs. These needs are expected to approach 500 mgd by the year 2020 and 1,000 mgd by the year 2070. Oklahoma City is planning to obtain water from storage in several Federal multipurpose reservoirs in southeast Oklahoma, some of which are already under construction. A report by the U.S. Public Health Service in 1962 entitled, "Water Resources Study, Southeastern Oklahoma and Southwestern Arkansas," contains a detailed study of Oklahoma City's use of southeastern Oklahoma waters.

b. Liberal, Kansas - The projected municipal and industrial demands of Liberal, Kansas are 13 mgd in 2020 and 29 mgd in 2070. The present sources of supply are wells yielding 4.5 mgd. This well system could be expanded to satisfy the required 2070 demand.

c. Guthrie, Oklahoma - The projected 2020 water supply demand for Guthrie, Oklahoma is 5 mgd, increasing to 14 mgd by 2070. Guthrie's present surface supplies provide a dependable yield of 2.25 mgd. Therefore, the city will need additional sources of water prior to 2020.

d. Stillwater, Oklahoma - In 2020 the projected water supply demand for Stillwater is estimated at 18.5 mgd, increasing to 27 mgd by 2070. Present surface supplies will yield 10 mgd. Therefore, Stillwater will need an additional supply 8.5 mgd by 2020 and 17 mgd by 2070.

e. Cushing, Oklahoma - The projected 2020 water supply demand for the Cushing area is 25 mgd, which includes a large industrial demand. This demand increases to 29 mgd by 2070. The city's present ground and surface water supplies have a yield of approximately 4.3 mgd. Thus a considerable expansion of the available water supplies in this area is needed.

f. Enid, Oklahoma - The City of Enid has an extensive well system yielding approximately 29 mgd. Projected demands for this area are 36.5 in 2020 and 49 mgd in 2070. Therefore, an additional source of water will be needed to meet future demands.

Future water supply demands in several other locations of the Cimarron River Basin study area will also exceed the present available supplies. However, in all instances, additonal supplies can be obtained by extending existing well fields.

IX. FUTURE WATER QUALITY

A. Water Quality Standards

1. Use of Stream - The water quality standards adopted by the States of Kansas and Oklahoma defined the water uses for the Cimarron River. In New Mexico and Colorado, the Cimarron River is an intermittent stream and a beneficial use of the intermittent flows has not been established by these States. In Kansas the mainstem of Cimarron River is used for agricultural purposes and recreation including sport fishing. The North Fork of the Cimarron River in Kansas is used for agricultural purposes, recreation including sport fishing, and receipt of treated wastes. In Oklahoma, the Cimarron River above the Little Salt Plains and all interstate tributaries are used for fish and wildlife propogation, recreation, public water supply, agriculture, aesthetics, and to receive treated wastes. Below the Little Salt Plains water uses have not been established for the mainstem of the Cimarron River since the high chloride concentrations presently preclude beneficial use of the stream.

2. Stream Standards - The States of Kansas and Oklahoma have established and adopted water quality control standards for the Cimarron River and its interstate tributaries designed to protect the water uses previously described. A partial listing of the specific criteria for the interstate streams is shown on Table IX-1. In addition both States have adopted general criteria covering the Cimarron River and the interstate tributaries. This criteria is quoted below:

a. Kansas - Mainstem of Cimarron River

> "The cumulative effect of waste discharges to the Cimarron River will be guided by the 1962 U.S. Public Health Service Drinking Water Standards except that for substances toxic to fish, standards generally accepted for fishery environment will be considered. Pollutional substances will be maintained below maximum permissible concentrations which would be detrimental for public water supplies, recreation requirements including sport fishing, agricultural needs, industrial needs, and other established beneficial use."

Table IX-1

Water Quality Standards Criteria Summary (Incomplete Listing)
(mg/l)

	T.D.S.	Max. Chloride	Max. Sulfate	Max. BOD	Min. D.O.	Range pH
Kansas						
Cimarron River - Mainstem	(See General Criteria)			-	4.0	6.5-8.5
Tributaries to Cimarron River	(See statement on General Criteria)					
North Fork Cimarron River	(See statement on General Criteria)					
Oklahoma						
Cimarron River above Little Salt Plains & all Interstate Tributaries	1266*	509*	173*	-	4.0	6.5-8.5
Tributaries to Cimarron	(See statement on General Criteria)					

* Weighted average quality (Interim Standard)

Note: Water quality standards for each of the states provide for a minimum treatment level of secondary for municipal wastes and its equivalent for industrial wastes.

b. Kansas - Tributaries to Cimarron River

"All waste discharges to tributaries of of the Cimarron River shall be controlled so that flows to the river will not reduce the quality of water in the mainstem Cimarron River beyond the limits of established criteria. Tributaries shall additionally be controlled so that public health hazards or nuisance conditions will not develop with tributary streams or drainage courses."

c. Kansas - North Fork Cimarron River

"The cumulative effect of waste discharges to the North Fork Cimarron River . . . and all tributaries thereto will be guided by the 1962 U.S. Public Health Service Drinking Water Standards except that for substances toxic to fish, standards generally accepted for fishery environment will be considered. Pollutional substances will be maintained below maximum permissible concentrations which would be detrimental for public water supplies, recreational requirements including sport fishing, agricultural needs, industrial needs, and other established beneficial uses. The above named streams and tributaries thereto shall be controlled so that public health hazards or nuisance conditions will not develop due to man-made discharges."

d. Oklahoma - Cimarron River above Little Salt Plains

"All tributary streams and all waste effluents shall be in such condition that when discharged to the stream reaches as defined, and Interstate Tributaries, they shall not create conditions which will adversely affect public health, or use of the water for beneficial purposes."

e. Oklahoma - Tributaries to Cimarron River

"The quality of tributary streams shall be controlled so that the quality of the river reaches as defined will not be lowered beyond the criteria set forth above. [See Table IX-1] In addition, adequate control shall be maintained to prohibit the development of public health hazards or nuisance conditions in such tributaries and maintain the highest current beneficial use of the waters pending a determination of the best usage and the establishment of specific criteria."

B. Natural Salt Pollution

1. General - The primary future water quality problem of the Cimarron River Basin will continue to be high chloride concentrations contributed from natural salt sources. Under existing conditions, the chloride concentration of the Cimarron River at Guthrie, Oklahoma exceeds 1,000 mg/l, 99 percent of the time. Based on the 1964 Public Health Service study, the U.S. Army Corps of Engineers has proposed to control the inflow of salt into the Cimarron River by constructing salt control structures at the three major salt sources in the Cimarron Basin. These structures will lower the concentration of chlorides in the Cimarron River at Guthrie, Oklahoma below 250 mg/l, for 25 percent of the time. In addition, the reduction of the chloride inflow into the Cimarron River will improve Keystone Reservoir by lowering the chloride content of the reservoir below 250 mg/l, 100 percent of the time. Several experimental structures have already been completed at other salt sources in the Arkansas-Red River Basins in hopes of determining the most feasible types of control. A brief summary of the proposed controls on the Cimarron River Basin follows. More detailed information is available in the Tulsa District, Corps of Engineers' survey report, "Arkansas-Red River Basins, Water Quality Control Study, Texas-Oklahoma-Kansas, Part II."

2. Big and Little Salt Plains of the Cimarron River

Because of their proximity, these two areas are considered as one source of natural chloride pollution. The control project would consist of a system of dams and channels for the impoundment of brine and the diversion of fresh water around the areas of contamination. Brine would be impounded, without any outflow, by a dam on Cimarron River at river mile 279.1. Relatively fresh water would be intercepted by a dam at river mile 4.0 on Buffalo Creek and at river mile 201.5 on Cimarron River. Releases from these fresh water reservoirs would be made through uncontrolled outlet works discharging into the respective diversion channels. The diversion channels would route releases around the brine reservoir and return the waters to the Cimarron River. Small dams would be employed to retard the runoff from the area to the northeast between the fresh and salt water reservoirs on the Cimarron River to minimize the size of the diversion channel. An uncontrolled emergency spillway would be provided at each of the Cimarron River dams. Control of 90 percent of the 4600 tons per day of chlorides is expected with this plan.

3. Salt Creek of the Cimarron River

The small drainage area above the salt source influenced the selection of the control plan. The plan consists of a brine reservoir to contain all surface runoff in addition to the brine flow from seeps and springs. The structure would be located at river mile 21.7 on Salt Creek. Storage would be provided for a 100-year event occurring on a 100-year accumulation of brine. This plan is expected to control 90 percent of the 250 tons per day of chlorides coming from this area.

4. Evaporation Effect on Englewood Reservoir

The average annual evaporation loss at the Englewood Reservoir site is approximately 92 inches per year. For the conservation pool of the reservoir, the average annual evaporation loss will be approximately 48,400 acre-feet per year, based on the surface area atop of conservation pool. On an annual basis, the flow in the Cimarron River at the reservoir site has exceeded the computed reservoir evaporation loss for the past 23 years. During drought periods there will be times when the average monthly evaporation loss could exceed the average monthly inflows and the chloride concentration in the reservoir would increase. Any buildup in the concentration of chloride in the reservoir would depend on the reservoir operation schedule, but would eventually reach an equilibrium where no additional increase would occur.

C. Municipal and Industrial Waste Returns

In the upper and middle portions of the Cimarron River Basin, municipal and industrial waste return flows are not expected to cause water pollution problems. This is due to three factors. The first is the lack of major urban or industrial centers which would discharge large quantities of waste. Second, extensive reuse of waste effluents will be made to meet industrial and irrigation needs. Third, due to the climate, most streams in the area are intermittent and waste returns are usually absorbed by the alluvium or evaporated before they reach surface supplies.

In the lower portion of the basin, there are two tributary streams which could be affected by future waste returns: Cottonwood Creek and Skeleton Creek.

Cottonwood Creek receives the treated effluent from a portion of Oklahoma City and several rapidly growing suburbs. Presently, during low flow periods the effects of these wastes are evidenced by a sewage odor in the creek despite secondary treatment of all wastes released to the stream. As the quantity of these wastes increase with the projected increasing population of the area, the problem could become severe.

Three possible solutions to this problem are, (1) advanced waste treatment, (2) a gravity flow pipeline to the Cimarron River mainstem where sufficient flows exist to adequately assimilate the wastes, and (3) pumping the wastes to the North Canadian River, which was proposed in the previously mentioned Public Health Service report on Southeastern Oklahoma. With either of these solutions, a regional sewerage system and treatment facilities could be developed by consolidating the small sewerage systems. This would provide uniform treatment of the wastes and a satisfactory disposal of the waste effluents. The most economical of the three possible solutions appears to be the piping of the waste directly to the Cimarron River.

The second tributary which may have a future water quality problem created by municipal and industrial waste discharges is Skeleton Creek. The City of Enid, Oklahoma presently discharges wastes in the headwaters of this creek. At the present time, the volume of Enid's wastes are not sufficient to cause a pollution problem. If population and industry develop in the area as projected, and the amount of waste returns increase proportionately, the flows in Skeleton Creek would not be sufficient to adequately assimilate the waste discharges. During periods of low flow, dissolved oxygen in the lower reaches of Skeleton Creek would be depleted, even though wastes receive secondary treatment prior to discharge.

The proposed plan of improvement includes the construction of a multipurpose reservoir on Skeleton Creek at river mile 12.0. This reservoir will extend a considerable distance upstream on Skeleton Creek. The reservoir, if constructed, would both help to solve the potential pollution problem and create a different one.

The volume of water in storage in the reservoir would be sufficient to adequately dilute the incoming wastes so that a depletion of dissolved oxygen caused by the biochemical oxygen demand of the wastes would not result. However, the small concentrations of nutrients (phosphorus and nitrogen) normally found in municipal wastes could develop an algae problem in the proposed reservoir if the nutrients are allowed to build up on the headwaters.

There are several alternates to avoiding a future algae problem in the reservoir. One would be the diversion of wastes around the reservoir. This would require a lengthy pipeline due to the headwaters location of Enid. The diversion of Enid wastes to another stream does not appear feasible as there are no streams in the Enid vicinity with sufficient flows to assimilate the wastes. A transfer to a nearby stream would not eliminate the problem, but create instead a problem on a different stream. A third alternate would be the use of waste returns for irrigation. This would require irrigable lands in the immediate Enid vicinity to be economical. The fourth solution would be advanced waste treatment to remove phosphates from discharged wastes. This alternative appears to be the most feasible, since Enid's present treatment plant utilizes the activated sludge process. Current research has shown that activated sludge treatment plants, with proper operation and design, can be adapted to high level phosphate removal.

D. Cattle Feedlot Waste

The high yields of feed grains, hay and wheat for livestock production have increased the occurrence of cattle feedlots within the study area in recent years. The wastes from these feedlots could be a problem in the future, if the runoff from the feedlots is not controlled.

E. State Plans for Water Quality Control

1. Oklahoma - Jennings, Oklahoma is the only municipality within the Cimarron River Basin in Oklahoma that presently is not providing secondary treatment for municipal wastes. The town is providing primary treatment of its wastes and is scheduled to complete construction of a secondary treatment plant in 1972. When this plant is completed, all Oklahoma towns within the Cimarron River Basin will have complied with the State's requirement of secondary treatment facilities for all communities. The State has also scheduled construction of collection systems and treatment plants in fiscal year 1971 at Chester, Oklahoma and in fiscal year 1972 at Carney, Dover, and Meridian, Oklahoma. These towns are presently using septic tanks.

2. Kansas - All municipalities in Kansas within the Cimarron River Basin have secondary waste treatment facilities. Four towns--Johnson, Satanta, Kismet and Protection--are developing plans for expanding its secondary treatment plants. Each of these towns has scheduled construction of additional treatment facilities for fiscal year 1970.

3. New Mexico and Colorado - All municipal collection systems for towns in the Cimarron River Basin within New Mexico and Colorado have secondary waste treatment plants. There are several communities within the area which do not have a municipal collection system and are using individual septic tanks.

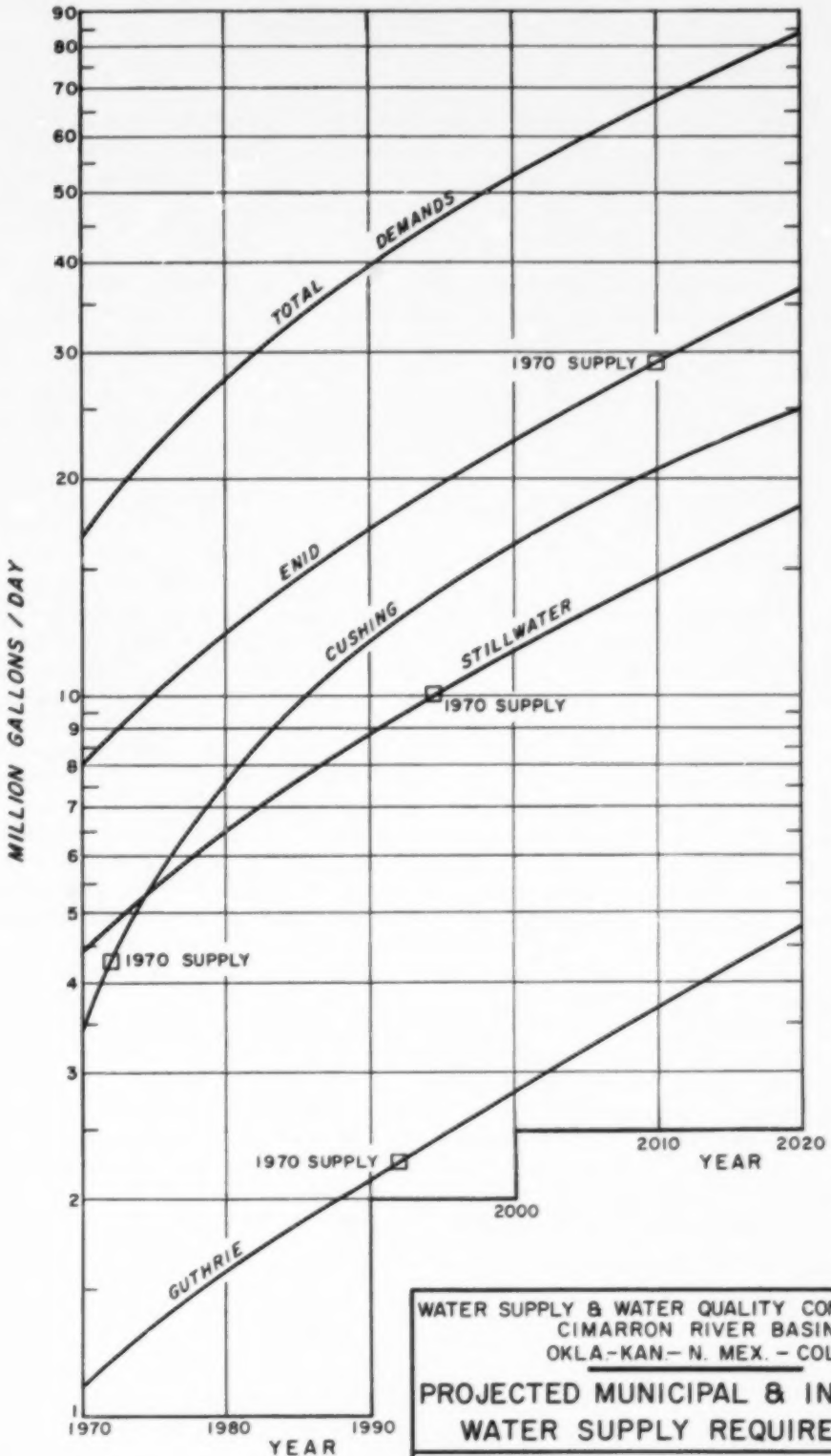
X. BENEFITS

A. General

The average annual benefits for including water supply storage as a project purpose in the Skeleton and Englewood Reservoirs will accrue from providing an adequate and dependable supply of water for municipal and industrial use in the study area. The Skeleton Reservoir will provide a dependable yield of 37 mgd for the towns of Enid, Stillwater, Guthrie, and Cushing, Oklahoma. This will be sufficient to meet the water supply needs which are expected to develop in these cities by the year 2020. [See Figure 5] Beginning in 2020, the 44 mgd yield from Englewood Reservoir could then be used by these cities to meet the anticipated increase in water needs expected after 2020. It is possible that prior to 2020 the yield from Englewood Reservoir could be exported to areas outside of the Cimarron River Basin.

B. Method of Evaluation

The benefits for including water supply storage in the Skeleton and Englewood Reservoirs were determined in accordance with Senate Document No. 97 (87th Congress Session). This document states that ". . .the measure of benefit will be approximate by the cost of achieving the same results by the most likely alternate means that would be utilized in the absence of the project." If the multiple-purpose Skeleton Reservoir is not constructed, the most likely alternate to meet the immediate water supply needs of Enid, Stillwater, Cushing, and Guthrie, Oklahoma is a single-purpose reservoir at the Skeleton site. The first cost, annual operation and maintenance, and major replacements for a single-purpose dam at this site were dtermined by the Tulsa District, U.S. Army Corps of Engineers, and used as a basis for determining the benefits to be realized by including water supply storage in the proposed Skeleton Reservoir. The alternative to providing water supply storage in the proposed Englewood Reservoir is a single-purpose project at the Englewood Site. The costs for a water supply project at this site was also determined by the Corps of Engineers and used to evaluate the water supply benefits for the proposed multiple-purpose Englewood Reservoir.



WATER SUPPLY & WATER QUALITY CONTROL STUDY
CIMARRON RIVER BASIN
OKLA.-KAN.-N. MEX.-COLO.

PROJECTED MUNICIPAL & INDUSTRIAL WATER SUPPLY REQUIREMENTS

UNITED STATES DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
SOUTH CENTRAL REGION DALLAS, TEXAS

FIGURE 5

C. Water Supply Costs and Benefits

The annual costs for the alternative single-purpose reservoirs were calculated by financing at the current 4-7/8 percent interest rate for the 100-year life of the project.

The first costs, including interest during construction, for the single-purpose water supply alternatives to the Skeleton and Englewood Reservoirs are $34,666,000 and $17,231,000 respectively. The average annual costs are $1,764,000 for the Skeleton alternative and $899,900 for the Englewood Alternative. Tables X-1 and X-2 show the first costs, annual operation and maintenance, major replacement and total annual charges for the single-purpose alternative.

The average annual benefits for including water supply storage in the proposed multiple-purpose Skeleton Reservoir are based on withdrawals beginning the first year in which releases are available. For Englewood Reservoir, the benefits are based on withdrawals beginning in 2020. Using the least costly alternative method, the annual water supply benefits accruing to the Skeleton and Englewood Reservoirs are $1,764,000 and $127,400 respectively. Tables X-1 and X-2 contain a summary of the benefit computations.

Table X-1

Water Supply Costs and Benefits
for Skeleton Reservoir

Cimarron River Basin

Annual Cost Equal Annual Benefits

Water Supply Alternative to Skeleton Reservoir to yield 37 mgd.

Construction Cost	$30,900,000
Interest during Construction	3,766,000
Net Investment	$34,666,000
Annual Charges	
Interest & Amortization 100 yrs. @ 4 7/8 percent	$1,704,500
Annual Operations and Maintenance	53,600
Major Replacement	5,900
Annual Cost = Annual Benefit	$1,764,000

Table X-2

Water Supply Costs and Benefits
for Englewood Reservoir

Cimarron River Basin

Water Supply Alternative to Englewood Reservoir to yield 44 mgd.

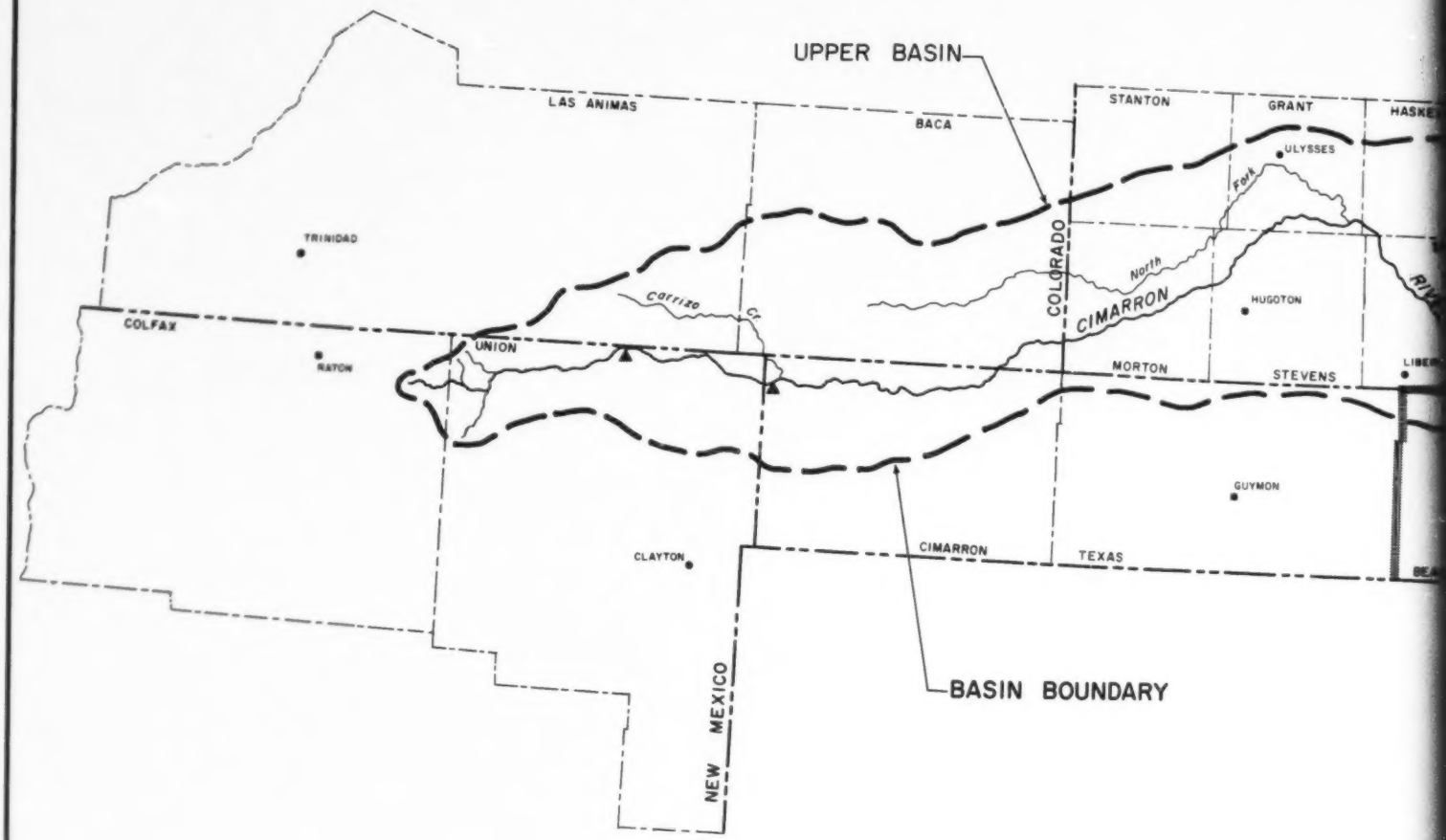
Costs

Construction Cost	$15,700,000
Interest during Construction	1,531,000
Net Investment	$17,231,000
Annual Charges:	
Interest and Amortization 100 yrs @ 4 7/8	$847,200
Annual Operation and Maintenance	41,600
Major Replacement	11,100
Total Annual Charges	$899,900

Benefits

Year of 1st Need - 2020

Annual Cost Capitalized for 60 yrs (2020-2080)	$17,398,000
Discounted 2020 to 1980	2,592,000
Present Annual Cost = Annual Benefit	127,400


UPPER BASIN
LAS ANIMAS
BACA
STANTON
GRANT
ULYSSES
TRINIDAD
COLFAX
RATON
UNION
Carrizo Cr.
North Fork
COLORADO
CIMARRON
HUGOTON
MORTON
STEVENS
GUYMON
CLAYTON
CIMARRON
TEXAS
NEW MEXICO
BASIN BOUNDARY

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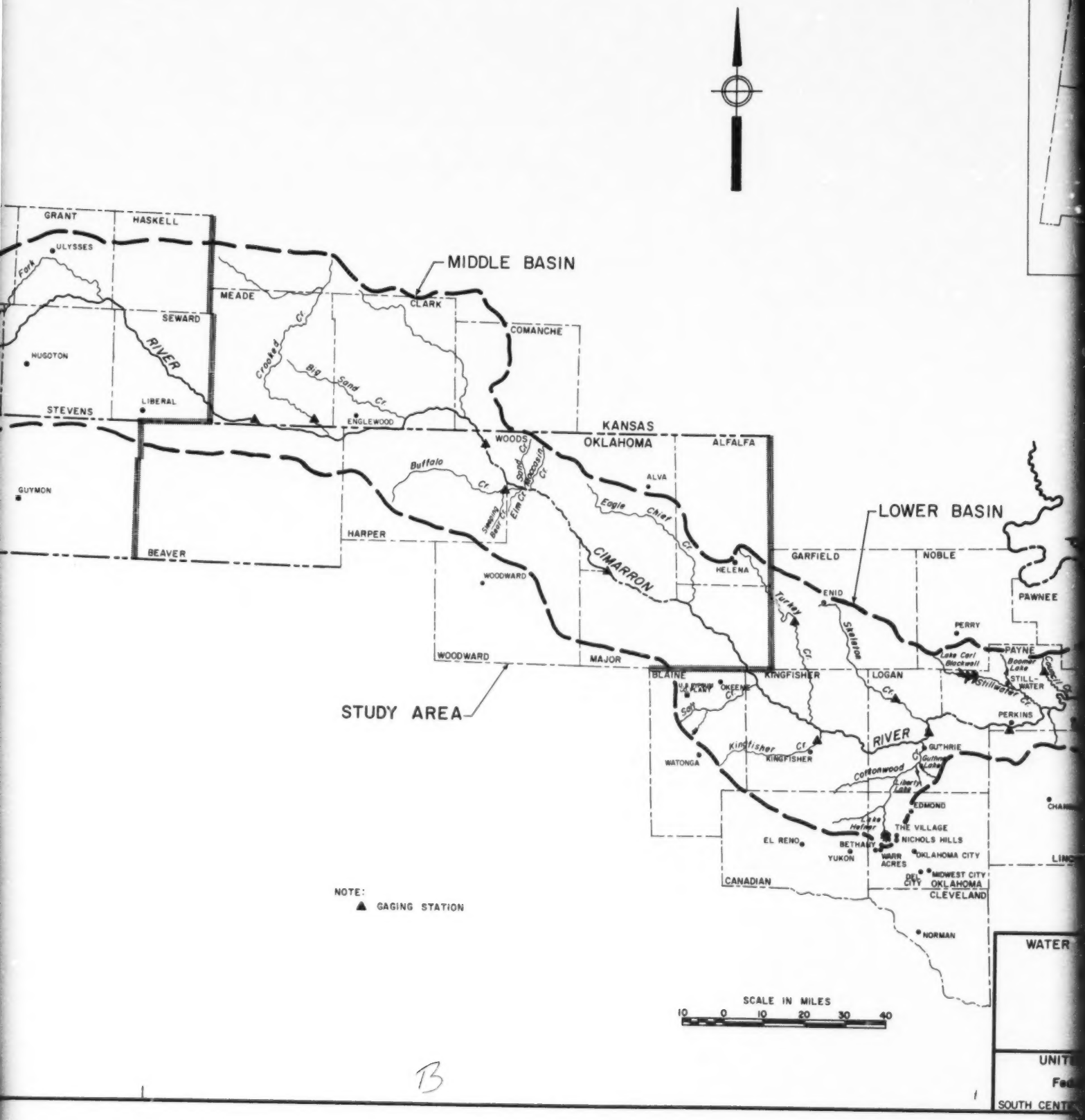
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HASKELL
ULYSSES
Fork
MIDDLE BASIN
MEADE
CLARK
SEWARD
COMANCHE
RIVER
HUGOTON
Crooked Cr.
Big Sand Cr.
LIBERAL
STEVENS
ENGLEWOOD
KANSAS
OKLAHOMA
ALFALFA
WOODS
Buffalo Cr.
Spring Cr.
Wolf Creek
ALVA
GUYMON
Eagle Chief Cr.
LOWER BASIN
HARPER
BEAVER
CIMARRON
HELENA
GARFIELD
NOBLE
WOODWARD
ENID
PAWNEE
Turkey Cr.
Skeleton
PERRY
PAYNE
Lake Carl Blackwell
Boomer Lake
STILLWATER
Stillwater Cr.
WOODWARD
MAJOR
BLAINE
KINGFISHER
LOGAN
Cr.
PERKINS
STUDY AREA
Salt
Kingfisher Cr.
RIVER
GUTHRIE
WATONGA
KINGFISHER
Cottonwood
Liberty Lake
EDMOND
Lake Hefner
THE VILLAGE
NICHOLS HILLS
EL RENO
BETHANY
YUKON
WARR ACRES
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MIDWEST CITY
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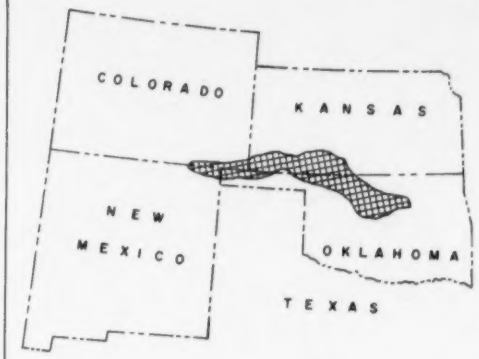
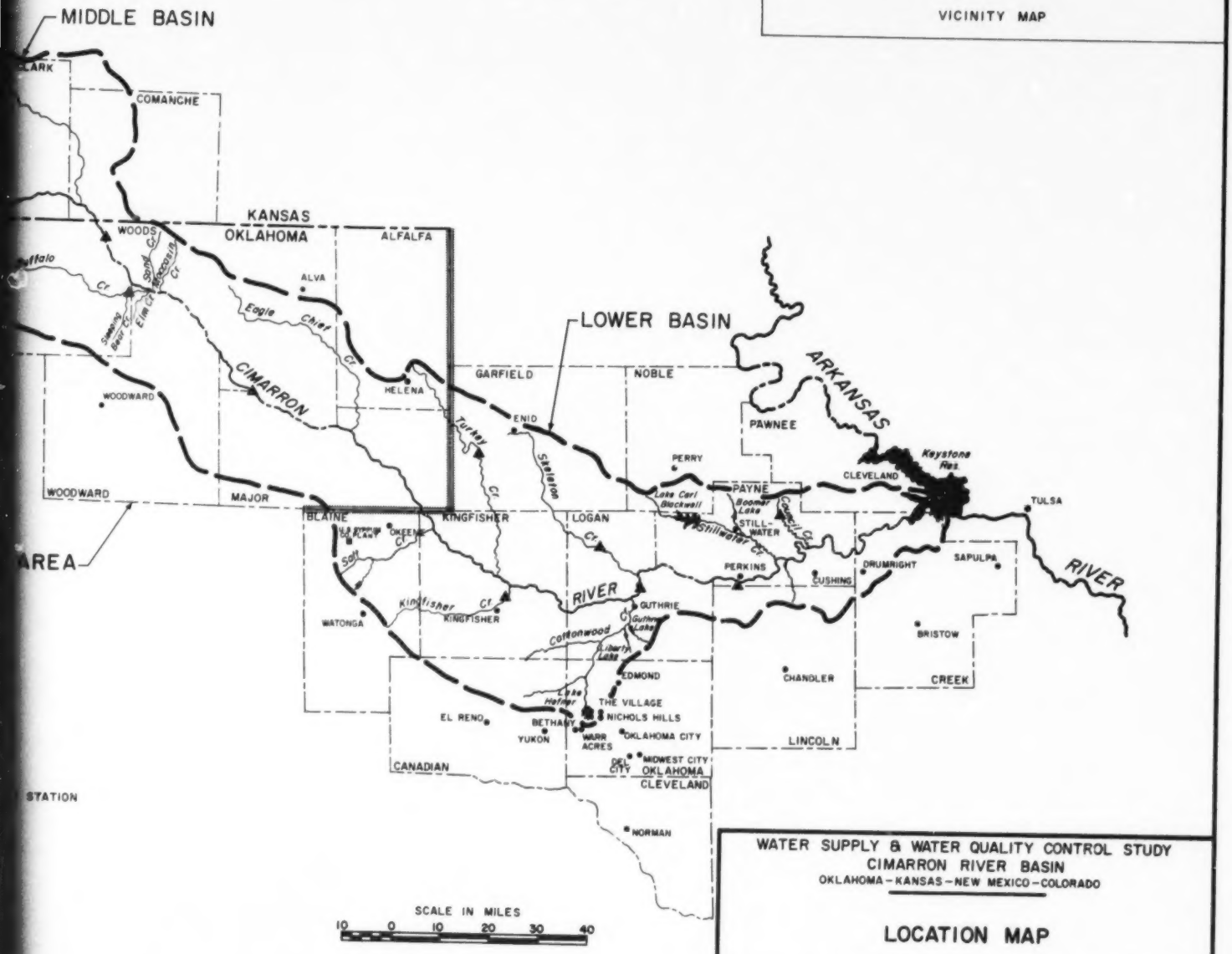


VICINITY MAP



WATER SUPPLY & WATER QUALITY CONTROL STUDY
CIMARRON RIVER BASIN
OKLAHOMA – KANSAS – NEW MEXICO – COLORADO

LOCATION MAP

UNITED STATES DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
SOUTH CENTRAL REGION
DALLAS, TEXAS

FIGURE 2